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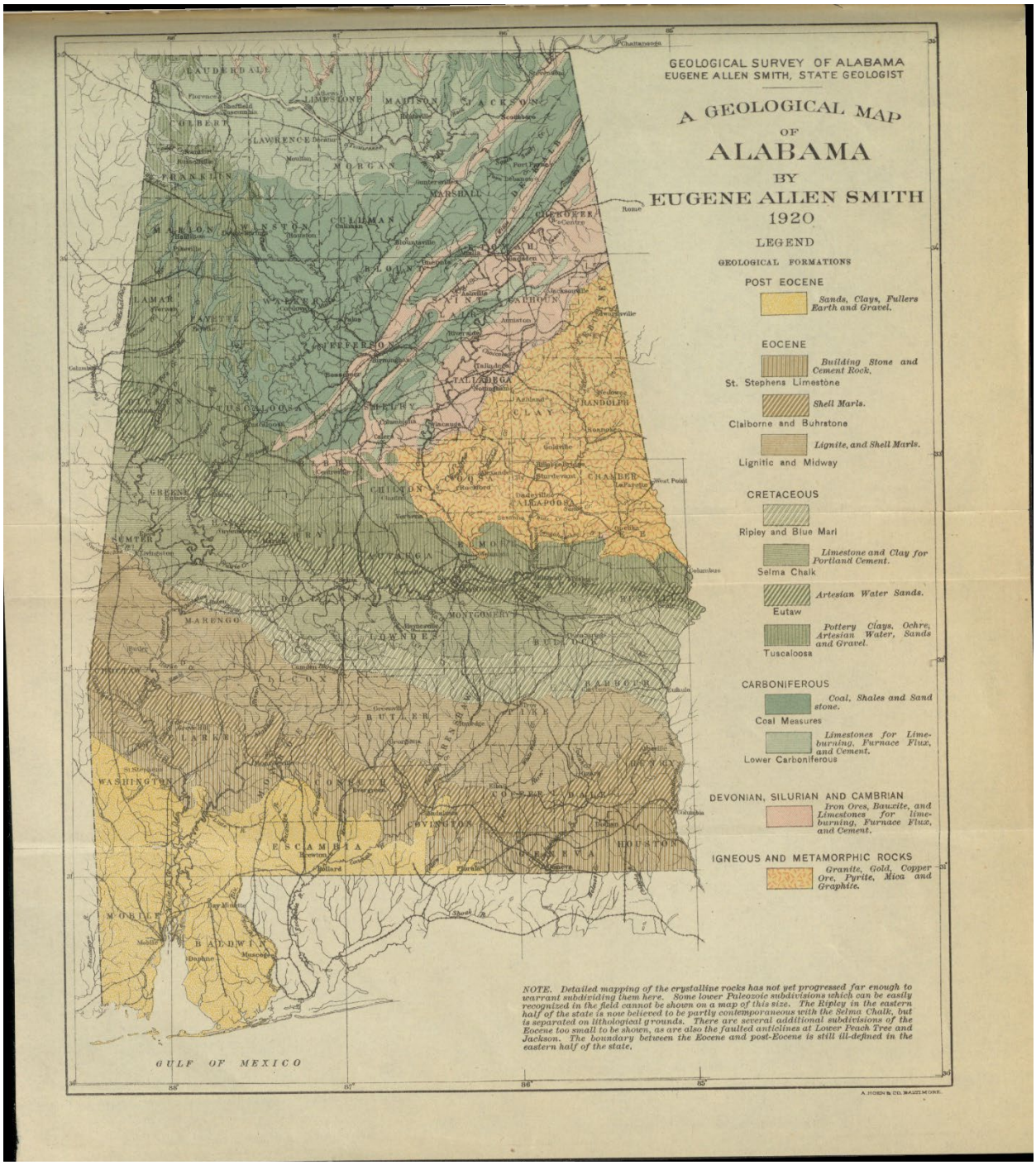
GEOLOGICAL SURVEY OF ALABAMA
EUGENE ALLEN SMITH, STATE GEOLOGIST
A GEOLOGICAL MAP
OF
ALABAMA
BY
EUGENE ALLEN SMITH
1920
LEGEND
GEOLOGICAL FORMATIONS
POST EOCENE
Sands, Clays, Fullers Earth and Gravel.
EOCENE
Building Stone and Cement Rock.
St. Stephens Limestone
Shell Marls.
Claiborne and Buhrstone
Lignite, and Shell Marls.
Lignitic and Midway
CRETACEOUS
Ripley and Blue Marl
Limestone and Clay for Portland Cement.
Selma Chalk
Artesian Water Sands.
Eutaw
Pottery Clays, Ochre, Artesian Water, Sands and Gravel.
Tuscaloosa
CARBONIFEROUS
Coal, Shales and Sand stone.
Coal Measures
Limestones for Lime-burning, Furnace Flux, and Cement.
Lower Carboniferous
DEVONIAN, SILURIAN AND CAMBRIAN
Iron Ores, Bauxite, and Limestones for lime-burning, Furnace Flux, and Cement.
IGNEOUS AND METAMORPHIC ROCKS
Granite, Gold, Copper Ore, Pyrite, Mica and Graphite.
NOTE. Detailed mapping of the crystalline rocks has not yet progressed far enough to warrant subdividing them here. Some lower Paleozoic subdivisions which can be easily recognized in the field cannot be shown on a map of this size. The Ripley in the eastern half of the state is now believed to be partly contemporaneous with the Selma Chalk, but is separated on lithological grounds. There are several additional subdivisions of the Eocene too small to be shown, as are also the faulted anticlines at Lower Peach Tree and Jackson. The boundary between the Eocene and post-Eocene is still ill-defined in the eastern half of the state.
GULF OF MEXICO
LAUDERDALE
COLBERT
LAWRENCE
MORGAN
MARSHALL
JACKSON
MADISON
FRANKLIN
MARION
WINSTON
CULLMAN
CHEROKEE
DE KALB
ETOWAH
CALHOUN
CLEBURNE
RANDOLPH
TALLADEGA
CLAY
LAMAR
FAYETTE
WALKER
JEFFERSON
SHELBY
TUSCALOOSA
GREENE
HALE
PICKENS
SUMTER
CHILTON
COOSA
CHAMBER
TALLAPOOSA
MACON
MONTGOMERY
LOWNDES
BULLOCK
MARENGO
WILCOX
BARBOUR
BUTLER
CRENSHAW
PIKE
COVINGTON
CONECUH
ESCAMBIA
HENRY
HOUSTON
WASHINGTON
MOBILE
BALDWIN
Chattanooga
Florence
Tuscumbia
Sheffield
Huntsville
Scottsboro
Decatur
Athens
Rome
Gadsden
Anniston
Talladega
Birmingham
Tuscaloosa
Selma
Montgomery
Eufaula
Troy
Dothan
Evergreen
Brewton
Mobile
Daphne
Columbus
West Point
LaFayette
Opelika
Greenville
Camden
Monroeville
Andalusia
Florala
Gainesville
Livingston
Demopolis
Marion
Jasper
Carrollton
Pickensville
Fayette
Russellville
Moulton
Guntersville
Fort Payne
Centre
Jacksonville
Oxford
Ashland
Goldville
Sylacauga
Roanoke
Wedowee
Columbiana
Calera
Alabaster
Montevallo
Centreville
Greensboro
Uniontown
Marion
Thomasville
Grove Hill
Jackson
Monroeville
Atmore
Bay Minette
Foley
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Imperfect: p. 65-96 - pages inverted

GEOLOGICAL SURVEY OF ALABAMA
EUGENE ALLEN SMITH, *State Geologist*

BULLETIN NO. 22

PETROLEUM POSSIBILITIES OF ALABAMA

PART I

NORTHERN ALABAMA

BY DOUGLAS R. SEMMES
Professor of Geology and Mineralogy
University of Alabama

PART II

SOUTHERN ALABAMA

BY J. E. BRANTLY

UNIVERSITY, ALABAMA
1920

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LETTER OF TRANSMITTAL

To His Excellency,

Governor Thomas E. Kilby.

SIR:—I have the honor to submit herewith manuscript of a bulletin on the Petroleum Possibilities of Alabama—Part 1, Northern Alabama, by Douglas R. Semmes, Professor of Geology and Mineralogy, University of Alabama; Part II, Southern Alabama, by J. Edward Brantly, Oil Geologist, Dallas, Texas, with the recommendation that it be printed as Bulletin No. 22 of the Geological Survey of Alabama.

Very respectfully yours,

EUGENE A. SMITH,

State Geologist.

May 1, 1920.

ERRATA.

On page 70, the number 18 in text and below cut should be 17.

On page 78, the number of the cut should be 18 instead of 17.

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INTRODUCTION

By DOUGLAS R. SEMMES.

IT IS not surprising that the marked impetus given the prospecting for oil and gas throughout the United States by the recent discoveries in Texas and Louisiana should be reflected to a certain extent in Alabama. During the past year or two the Geological Survey has daily received inquiries as to the possibilities of oil and gas in all parts of the State, and at the present time there seems to be greater activity and interest than ever before. This increasing demand for information regarding the geology of many parts of the State from the point of view of oil and gas production has demonstrated the advisability of presenting in one bulletin all the information that has in the past been scattered through various publications both of this survey and elsewhere, and also the results of field examinations made by the writer in many parts of the State. Owing to the limited time at the disposal of the writer for field work only the more favorable and significant areas could be covered. In other areas the results of previous workers have been summarized and interpreted in the light of present developments. In this way the actual aim of the bulletin, the collecting of all information regarding the oil and gas possibilities in Alabama, is accomplished.

Actual prospecting for oil was first begun in this State in 1865, when the Watson wells were drilled in Lawrence County, though the *Niles National Register*, of August 14, 1841, gives an account of finding oil during dredging operations for the removal of the McGrew shoals on the Tombigbee River. According to this account quite a quantity of the oil was collected, which burned readily on ignition. In 1899, a well was completed in Lawrence County, the production of which was reported at twenty-five barrels per day. After the opening of the Spindletop pool in Texas in 1901, prospecting was carried on much more briskly in this State and a number of test holes were completed in the coastal plain. The discouraging outcome of these tests caused a lull in developments, and it was not until 1916 that the discov-

eries in Oklahoma and Texas and the increasing price of crude oil spurred on the prospectors to additional efforts in Alabama. Since then there has been a continual increase in development activity and at present time there is no indication of waning interest.

ORIGIN OF OIL.

The question of the origin of oil has been a point of contention among investigators since the first definite theory was advanced some fifty years ago. The controversy grew most intense towards the latter part of the past century, when the majority of investigators became converted to organic theories, leaving the exponents of the earlier inorganic theories considerably in the minority. Since no feasible theory for the converting of organic material into such a homogeneous mixture of hydracarbons as petroleum could be readily suggested the earlier investigators, with little actually reliable data at hand, were rather united in attributing to oil an inorganic origin.

Inorganic Origin.—The most generally accepted of the inorganic theories was that brought forth in 1877 by Mendelieeff, who argued that there probably existed in the interior of the earth large quantities of iron carbide and that the action of downward percolating surface waters on this carbide of iron would produce petroleum. Actual observations in the known oil pools have later conclusively shown that no such reaction could have taken place. However, since certain oil pools are closely associated with igneous rocks, and since as yet no oil just similar to natural petroleum has been produced by the artificial distillation of coal or any such organic substance, certain investigators still remain unconverted to the organic theories. One of the main points of the supporters of the inorganic theory is that petroleum has been found in small globules in igneous rocks. However on microscopic examination this oil proved to be optically inert, while all oils of commercial importance are optically active. These points taken together with the known association of all oil pools with sedimentary rocks and the complete absence of igneous rocks of any kind within great distances of certain important pools has caused the inorganic theories to be virtually discarded. At present practically all assent to the organic origin of oil, though the

exact process by which the organic material is converted into petroleum is still unsettled.

Organic Theories.—The supporters of the organic theory are today divided mainly into those who believe that oil and coal alike are derived from land plants, and those who believe marine organisms, chiefly animal, form the main part in the original material of petroleum; but some investigators contend that the material is of both sources.

The earlier superficial observers describing oil in connection with coal and similar substances considered it to be formed from fossil land plants by distillation. Others considered that certain land plants, or land plants in certain localities, have in some cases undergone a special mineralization to liquid and gaseous hydrocarbons rather than to coal. Since that time, however, closer observation has shown that oil is rarely intimately associated with coal and that it is found in sedimentary rocks that from their fossil content show that they were deposited under marine rather than terrestial conditions. Moreover it has been shown that very high temperatures would be necessary to convert vegetable material into petroleum and leave no trace of the original plant structure. In the large deposits of asphalt in Trinidad lignite was found closely associated with the asphalt, and the earlier observers considered them to be of the same origin. Later it was discovered that the asphalt was composed of a mixture of small marine shells, and also pieces of lignite and plant remains were both found in the asphalt itself, showing conclusively that the asphalt could not have been derived from the lignite or the plants as these were found still unchanged.

More recently laboratory experiments have shown that vegetable material could be distilled into petroleum but only at very high temperatures. The petroleum thus formed is of a paraffin base, such as the oils of Pennsylvania. This discovery led to the theory advanced by Peckham that the oils of paraffin base were probably of plant origin, while those of asphaltic base were derived from animal material.

Summarizing the points against the origin of oil from land vegetation:

1. There is usually no connection between coal-bearing and oil-bearing strata. This is well shown in the Appalachian region where the coal-producing measures are barren of oil and vice versa.

2. Where lignite and plant remains are accidentally associated with bitumen deposits they retain their normal character.

3. There is geologic evidence that no such temperature as would be required to distil oil from vegetable material ever existed in the areas of greatest oil accumulation.

4. In certain areas oil is found in limestone and other marine sediments that contain no traces of terrestrial vegetation.

5. Even those oils distilled at high temperatures from coal are quite unlike natural petroleum.

The above points indicate that it is improbable that oil is derived from the distillation of land plants, except the possibility of such distillation in areas where igneous material has been intruded into sedimentary rocks rich in vegetable material of such nature.

This, therefore, restricts the origin of oil to animal material—chiefly marine, since the land animals would obviously be only rarely and accidentally preserved—and vegetable material of marine origin such as the marine algae.

This dual origin of petroleum is now accepted by the large majority of investigators, and it only remains to determine the nature of the processes that brought about the change from the original marine animal and vegetable material to the oil. Everyone who has closely examined any extensive region of sedimentary rocks is impressed with the abundance of marine shells and other indications of prevalent marine animal life at the time of deposition. It is rare that land animals are thus preserved, but occasionally beds composed almost wholly of the bones of land animals have been found, and in one instance (Ventura County, California) these remains are directly associated with an asphalt deposit. The marine vegetation is rarely preserved in recognizable form, so that we are unlikely to appreciate the importance of this source of organic material unless we consider its abundance in the present sea.

These marine organisms, especially the animals, sink to the bottom on dying and there accumulate in an environment almost wholly free from oxygen. Under these conditions a slow decomposition is set up, chiefly through the agency of certain denitrifying bacteria. In this way the nitrogenous tissues of the organism are decomposed and eliminated soon after death leaving only the fatty parts

and oils. These fats are comparatively stable but by slow decomposition through long ages of time at rather low temperatures they are changed over into natural petroleum. This theory, termed the Engler-Hofer theory, has been fully outlined by Dalton* and has now been generally accepted as agreeing with known facts and on the whole having the greatest degree of probability.

According to this theory then it is the marine organic material that has played the principal role in the origin of oil, and it is quite possible that the paraffin-base oils are derived from marine vegetable material, chiefly marine algae, while the asphaltic-base oils may be derived from marine animal organisms.

It should be kept in mind that no distinction is made between land and marine animals in themselves, but the distinction is made in the nature of the environment of the two after death. It is quite plain to all that animals dying on the land where oxidizing influences are active would be rapidly and completely decomposed and all the volatile parts carried off into the atmosphere. Therefore it is only in the sea where non-oxidizing conditions prevail that petroleum will be formed, and accordingly it is only in the marine sediments, the black and brown shales and dark impure limestones that deposits of oil may be expected. According to Schuchert,** "All rock formations accumulated directly beneath the atmosphere, as the pure continental deposits, must therefore be devoid of commercial quantities of petroleum. Then, too, all deposits either of the fresh waters or of the seas, which are periodically subjected to atmospheric weathering during their time of accumulation, are also lacking in oil in paying quantities. Hence, we may further conclude that all red or reddish, yellowish, or white, rain-pitted or sun-cracked deposits, either of continental, fresh-water or semi-marine origin, are lacking in petroleum in large amounts."

Therefore the nature of the sediments deposited and the conditions of their deposition are of utmost importance in determining the possibilities of a new area. In Alabama, considering the formations of the northern part of the State,

* Leonard V. Dalton: On the Origin of Petroleum, Econ. Geol., Vol. 4, pp 603-631 (1909).

** Charles Schuchert: Petroliferous Provinces, Discussion, Mining and Metallurgy, No. 155, pp. 3058-3070, Nov. 1919.

the Coal Measures are of dubious value, though its extensive shale series developed in certain localities is probably in great part of marine origin and of value in the generation of petroleum. The limestones of the Subcarboniferous are typically of marine origin and throughout them oil is found disseminated. Likewise the limestones of the middle and lower Paleozoic, (the Niagara, Trenton and Knox) are of marine origin, and though in part widely dolomitized, still they show oil dissemination in places.

The formation of the central and southern parts of the State can be considered likewise. Beginning with the Tuscaloosa formation of Cretaceous age, it is found to be of continental or fresh-water origin and therefore no oil should be expected in it. The succeeding Cretaceous formations show more and more the characteristics of marine sediments as one goes toward the coast, until we reach the Selma Chalk, which is undoubtedly marine. Beyond this the Eocene formations show locally both marine and near-shore or brackish water characteristics and are of dubious value. It should be remembered, however, that in the southern part of the State drilling started in the Eocene formations would probably be continued to the depth of the Tuscaloosa series which at this point, being farther removed from the Cretaceous shore-line, might possibly be a marine series and a potential oil producer. So it is readily seen that the examination and appreciation of the character of the sediments most favorable for oil production is of great significance in attempting to predetermine the area of the greatest possibility in Alabama.

MIGRATION OF OIL.

From the above brief outline of the present accepted theory it is evident that the mother-rocks of petroleum are the dark petroliferous shales of marine origin and similar impure limestones, yet all shales are not oil shales. Schuchert* estimates that only from ten to fifteen per cent of the shale formations are decidedly petroliferous, the greater majority being, as he expresses it, mere mudstones deposited in fresh or brackish waters, or as lake or river deposits, or as marine deposits under conditions of sparsely developed life, or under conditions where the preservation of the fatty

* Op. Cit., p. 3064.

portions of the existing organisms would be improbable. So we see that it is only occasionally that the conditions are favorable for the preservation of the fatty portions of the organisms in the marine sediments and the development of typical petroliferous shales.

Granted that the shales are the mother-rocks of oil we must next explain the fact that large accumulations of oil are rarely found in shales, but rather in sandstones and other sedimentary rocks of considerable pore space. That is, the oil formed in shales and similar formations, has in some past time, in large part left the shales and migrated into other sedimentary formations.

The rapidity and facility with which this migration takes place and the kind of formation selected as a reservoir by the oil will depend upon a number of factors, some of which are of much significance in the accumulation of oil in commercial quantities.

Hydrostatic Pressure.—Beneath the surface in all parts of the earth there is a zone in which the rocks are saturated with water. Its depth varies with the amount of rainfall and the nature of the topography. The weight of the water causes it to extend downward as far as any fissures or pore-spaces remain in the rocks. The surface tension of water is about three times as great as that of oil, and therefore capillary attraction is thrice as effective in drawing water into the more minute cavities of capillary size as it is for oil.* If oil was originally formed in fine-grained shales occurring disseminated in minute globules the effect of hydrostatic pressure in conjunction with capillary forces would be to force the oil out of the shales and into formations containing larger pore-spaces. In Southern Alabama, the formations, gently inclined with the slope of the country to the south, are saturated with water under considerable head and in places water will rise in wells to the surface and make an artesian flow. This is because the formations obtain part of their water content from their outcrops farther to the north and at greater elevations. Therefore, in the coastal plain of Alabama we may expect good hydrostatic pressure and the oil, if there is any, will migrate and accumulate more freely.

* The Capillary Concentration of Gas and Oil, by C. W. Washburne, Trans. Am. Inst. Min. Engrs., Vol. 50, pp. 829-842, 1914.

Character of the Formation.—It is obvious that oil will migrate more freely in a porous sandstone or limestone than in a fine-grained shale or clay. Moreover certain sandstones are much more porous than others and offer better channels for the migration of oil and reservoirs for its storage. In this connection the microscopic examination of the sediments in question is often of much importance in attempting to predetermine their effect upon the migration of oil contained within them.

Dip of the Strata.—Since oil is lighter than water it will rise, and the general tendency of its migration will be toward the surface. In this way a vast amount of oil formed during past geological time has migrated to the surface and been lost. The oil now accidentally entrapped to form the known pools probably constitutes less than one per cent of all the oil originally formed in the sedimentary rocks. Since oil migrates more rapidly in porous formations it will obviously move even faster and more completely toward the surface if the formation is vertical. So the angle of inclination or the dip of the strata must be considered a rather influential factor in oil migration.

Nature of the Oil.—The specific gravity of oil will affect at least the rate of migration even though it may not alter the final result. Certain crude oils, such as some of the Mexican oils, are so viscous that they must be heated before they will flow at all, while others are so light that they are much more fluid than water.

Extent of the Migration.—The fact that oil is found in isolated and unrelated pools is sufficient evidence of the fact that it has migrated from its original disseminated condition in petroliferous shales to points that favor its entrapment and accumulation. That a certain amount of migration has taken place is conceded by all investigators, but at present there is a tendency by some to question the previously accepted ideas regarding the extent and mechanics of this migration. The actual extent of migration is of vital importance in certain regions where the prospective series does not contain any large amount of bituminous matter, and where oil accumulation, if any exists, must have been brought about by comparatively long-distance migration. The geologist, therefore, too often concludes that given the favorable conditions of structure and storage, oil will ac-

cumulate even from a series poor in bituminous matter by extensive migration and concentration of the petroleum content at some favorable point. A careful appraisal of the conditions in a large variety of oil fields leads the investigator to the conclusion that the factors determining the extent and efficiency of migration are exceedingly complex, and with our present lack of knowledge regarding many of the contributory factors it is impossible for one to come to any definite conclusion, nor would it be possible to lay down any set of principles that would hold good for any number of fields.

Recently certain very suggestive experiments have been performed by Alex W. McCoy* that throw additional light upon both the origin and migration of oil. Mr. McCoy subjected oil shale to intense pressure by compressing it in a tube, the central portion of which was thinner to allow bulging; thereby inducing flowage in the shale, and without causing an appreciable amount of heat, developed small globules of oil. The material used was typical oil shale capable of yielding about 25 gallons to the ton, but no oil could be removed by solvents prior to the experiments. Mr. McCoy concludes from these experiments that solid bituminous material in the mother formations is only changed to petroleum by pressure in the local areas of folding, that is, the pressure accompanying the actual folding which might give rise to the anticline in which the oil is later entrapped, originally caused the formation of the oil from the bituminous mother rock. Moreover, he concludes that the entire amount of oil in any field could readily be derived from the bituminous shale in close proximity to the producing horizon; and that extensive migration does not occur, because away from the area of movement and associated pressure the oil would not be formed, and also the bituminous shales immediately adjacent to the point of accumulation are amply sufficient to produce the oil in the existing pool. This, however, presupposes a comparatively highly bituminous shale series immediately associated with the oil bearing horizon, which is not always the case. Moreover, in Wyoming where there do occur extensive shale series there is almost conclusive evidence of long distance migration, for there we find the pay sand drained of its oil content for many square

* Notes on Principles of Oil Accumulation, Jour. Geol., Vol. 27, pp. 252-262, 1919.

miles, the oil having migrated along the axis of elongated anticlines for sometimes 10 or 15 miles to the highest point of the structure.

In the coastal plain of Alabama there is no such highly bituminous shale series, so that the potential oil content per cubic foot would hardly compare with that of the prolific Mowry shales of Wyoming. There will not be, therefore, sufficient oil derived from the immediately adjacent mother rocks to fill or partly fill the known structures. So if we preclude the possibility of comparatively long-distance migration we greatly lessen the possibility of the occurrence of oil in commercial quantities in this region.

OIL RESERVOIRS.

Those sedimentary formations containing the largest amounts of pore space are naturally the best adapted for oil reservoirs.

Sandstones.—Of those sediments usually found in a marine series the sandstones are the commonest reservoir-rocks for oil. The porosity in the average sandstone varies from 5 to 25 per cent. The normal oil sands average around 10 to 15 per cent. It occasionally happens that sandstones which are normally quite porous are locally cemented and indurated by circulating siliceous waters and their value as oil reservoirs much impaired. The percentage of porosity can readily be determined by physical tests or by microscopic examination.

Limestones.—The porosity in limestones varies from 0.5 to 13 per cent. Some limestones contain sandy layers where the pore space may run as high as 15 per cent. This is true of the Tuscumbia and Trenton limestones of the northern part of the State. Such horizons would consequently form good oil reservoirs.

Dolomites.—By certain processes not clearly understood by geologists limestone is sometimes changed from the pure calcium carbonate to a mixture of calcium and magnesium carbonates. This change is attended by a certain amount of shrinkage and resultant cavity formation. Therefore in certain dolomites the amount of cavity and pore space runs rather high. This is the case with the Knox dolomite; but for other causes that will be discussed later the Knox is not considered a favorable horizon for oil.

Cavities.—Even though enormous quantities of oil may be derived from one well yet it rarely happens that there are actually cavities in which the oil is stored. It is possible, however, that cavities formed in limestones by the solvent action of underground water may subsequently become filled with petroleum and play an important role in the origin of small pools.

THE ACCUMULATION OF OIL.

We have seen that oil migrates freely along porous, inclined strata and that the general tendency is upward rather than downward. So if we consider the strata folded in the form of an arch, the oil should rise to the crest of the arch and there remain entrapped (Fig. 1), if there is an impervious stratum above, and since we have to deal with three dimensions the oil would migrate along the pitch of the arch (unless it were horizontal) until it reached the highest point. A fold, therefore, in which the strata dipped away in every direction from a central point would be the ideal trap for oil. Such a structure is termed a dome or quaquaversal structure.

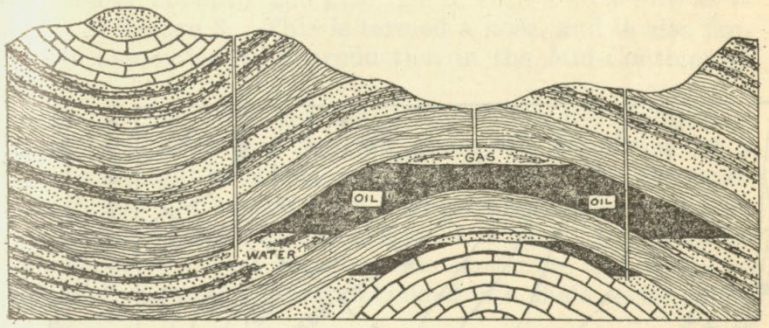

FIG. 1. Cross-section showing the idealized occurrence of oil, water and gas in an anticline. The lower oil-producing sand shows local thinning near the axis of the fold thereby decreasing the size of the reservoir and the amount of production from this sand.

Anticlinal Theory.—This connection between structural arches or anticlines and oil pools was recognized as early as 1861 by T. Sterry Hunt, but it was not until 1892 that the idea was fully developed and put to practical test by I. C. White.* In certain areas, however, it was soon discovered

* Geol. Soc. Amer., Bull. 3:187, 1982.

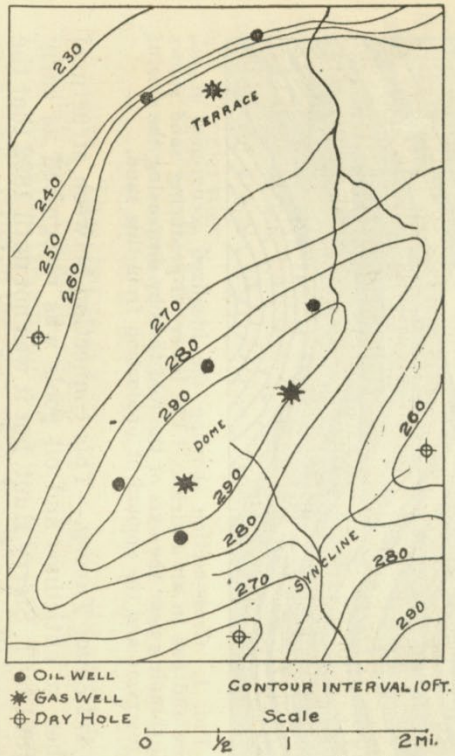

FIG. 2. Structural contour map showing a dome and terrace expressed by contours projected on the producing horizon. Terraces of this nature are often productive in Texas.

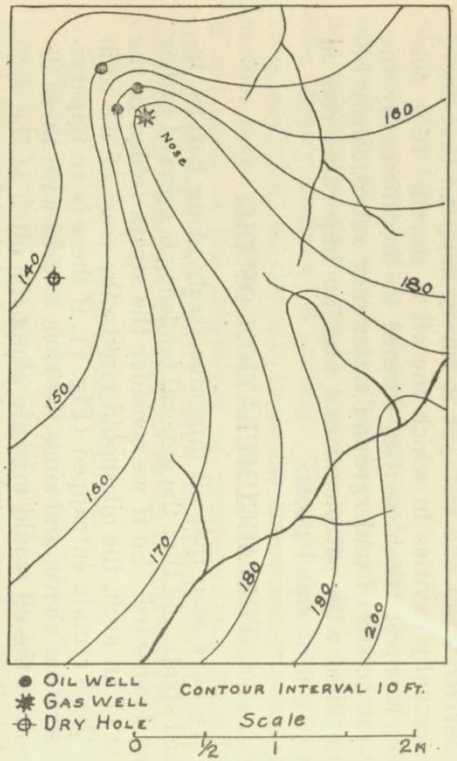

FIG. 3. Structural contour map showing a plunging anticline or nose with the production associated with a change in the pitch of the axis.

that the synclines or structural troughs produced more oil than the anticlines. This was readily explained by the fact that in these areas the porous stratum in which the oil moved was practically devoid of water and without hydrostatic pressure the oil sank to the lowest points, the synclines, instead of accumulating along the axes of the anticlines.

Domes.—Since the development of the anticlinal theory it has been recognized that oil and gas will accumulate in numerous kinds of structural traps other than anticlines and synclines. As has been stated, the ideal trap for oil is the dome, especially in areas of strong hydrostatic pressure such as Wyoming. In the accompanying illustration (Fig. 2) a dome is depicted by contours projected upon the surface of the oil-bearing sand.

Noses and Terraces.—Oil migrating up an inclined stratum may possibly come to rest where the dip lessens abruptly and the strata become approximately horizontal. Such a structure is termed a terrace; in Oklahoma and Texas such terraces are often underlain by moderate-sized pools. At other points the strike or direction of outcrop may change abruptly and give rise to such a structure as is shown in Figure 3. This is termed a nose, and is also frequently associated with production in the Mid-Continental fields.

Sand Lenses on Monoclinal Slopes.—The particular geological conditions that brought about the deposition of a sandstone might have been essentially local so that the sandstone would not extend over a great area, but occur over only a limited area in the shape of a lens. If elsewhere shale deposition were going on this sandstone lens would be completely surrounded and imbedded in a shale series. The

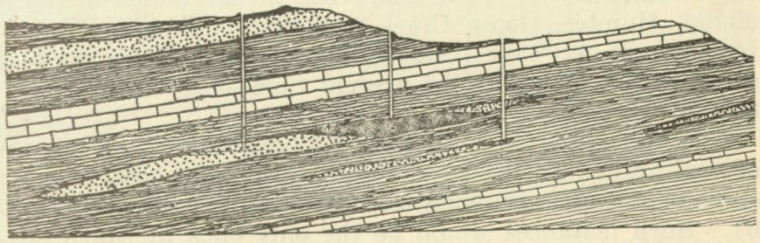

FIG. 4. The occurrence of oil in a lenticular sand, interstratified in a gently dipping sedimentary series, the principle of accumulation being the same as in an anticline.

effect of hydrostatic pressure would be, therefore, to force the oil and gas from the shale into the sandstone and there it would be separated into layers of gas, oil and salt water, as illustrated in Figure 4, by gravity.

Salt Domes.—In Louisiana and Texas there occur large masses of salt in the Tertiary and Cretaceous formations of the coastal plain, which are usually expressed on the surface as slight topographic elevations. These elevations have been explained by the force of the crystal growth of the salt beneath resulting in the gradual arching up of the overlying formations (Fig. 5). In this way a dome is

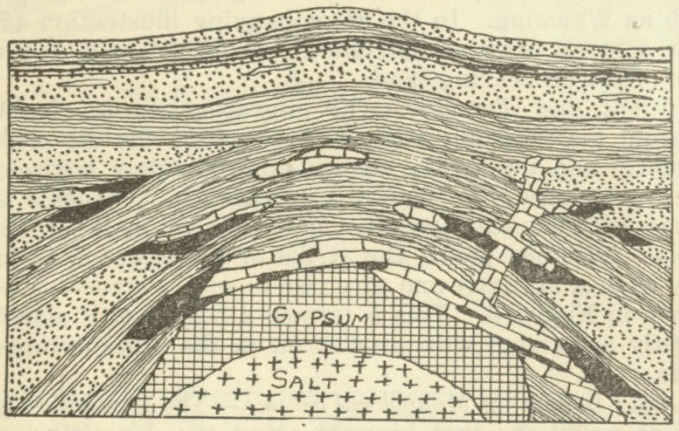

FIG. 5. Generalized section of a salt dome (after Fenneman) showing the irregular distribution of the oil associated with such structures and the lengthy period of dome growth as indicated by the unconformities in the overlying sediments.

made and in some cases oil accumulation is associated with these structures, as is the case with the salt domes at Spindletop, Humble, Goose Creek and West Columbia, Texas. In Alabama we have formations of similar character and geologic age, but up to the present time no salt domes have been discovered.

Volcanic Plugs.—In Mexico volcanic rocks have intruded and arched up the surrounding sediments, and in some cases very large accumulations of oil have developed (Fig. 6). Such instances would be the only ones in which sufficient heat would develop to possibly cause the distillation of oil from land vegetation.

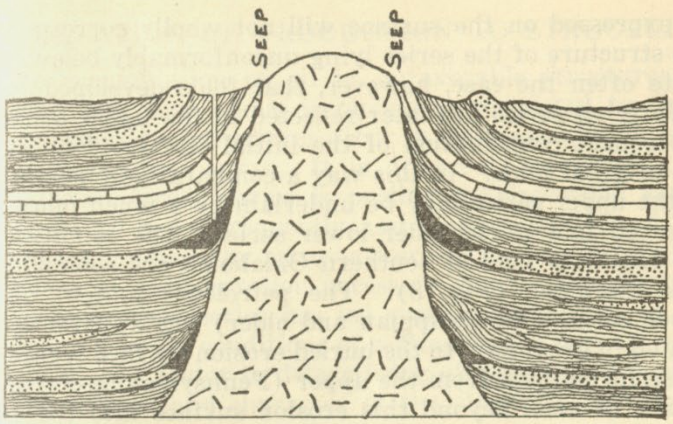

FIG. 6. Generalized section of a petroliferous series intruded by a volcanic neck or a dike, and the subsequent accumulation of oil in the upturned strata. Much of the oil of Mexico has accumulated under structural conditions of this nature.

Faults.—Petroliferous formations may sometimes be broken by dynamic processes and the reservoir rock effectually sealed by being brought into juxtaposition with impervious shales as is shown in Figure 7. In some of the Asiatic fields this type of trap is occasionally encountered.

Unconformities.—It sometimes happens that a petroliferous series is deposited, consolidated, then uplifted and folded, and later subjected to erosion, and on top of this folded and eroded series is deposited another series which may or may not be petroliferous. In such a case the overlying series is said to be unconformable with respect to the underlying. It is obvious that in such a case the structure

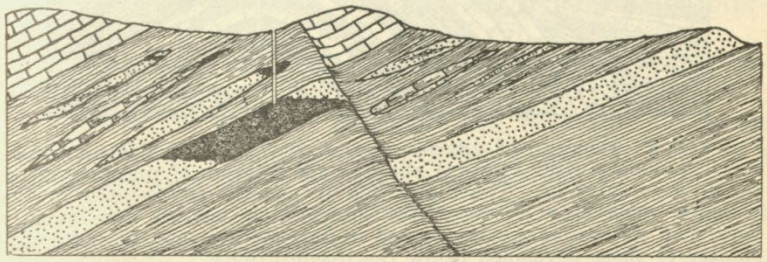

FIG. 7. Oil accumulation associated with a faulted petroliferous series in which the oil sand has been effectually sealed by being brought into juxtaposition with an impervious shale series.

as expressed on the surface will not wholly correspond to the structure of the series lying unconformably below. It is quite often the case, however, that folds developed in the underlying series are later reflected in the upper series by subsequent continuation of the initial stresses that caused the original folds. In this way a comparatively gentle fold in the upper series may be underlain by a much more pronounced fold in the older lower series. The conditions in the Healdton field of southern Oklahoma are somewhat of this character (Fig. 8). The petroleum content of the lower series (Mississippian and older) has apparently migrated in great part to the buried erosion surface separating those formations from the upper (Pennsylvanian-Permian) series, or even beyond this erosion surface into the sands of the Pennsylvanian. Production, therefore, does not always occur in direct relation to the surface structure, and some of the most prolific horizons are closely associated with the erosional surface separating the two series. Somewhat similar conditions occur in the Ranger field of Texas, where relatively unimportant noses and terraces (Fig. 3), are represented in depth by pronounced structures, of the same variety, and the greater part of the production comes from the upper limestones of an underlying unconformable series.

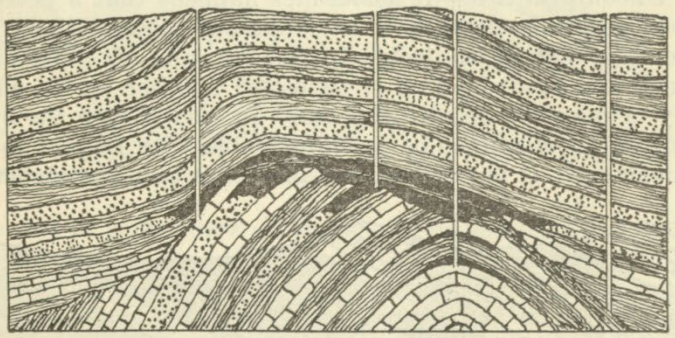

FIG. 8. Generalized cross-section of the Healdton field of southern Oklahoma (after Powers) showing the relation of unconformities to oil accumulation. The older fold is usually represented in the younger series by a less intensive deformation, but the subsequently developed structures as determined at the surface may be quite dissimilar to those developed below the unconformity.

THE RELATION OF PRODUCTION TO STRUCTURE.

The accumulation of oil in unfavorable structures of the kind described above is obviously restricted to those regions where the structures occur in close association with petroleum-bearing series. It is apparent, moreover, that if the petroliferous series is prolific the favorable structures will be more frequently and more completely filled. The recent emphasis by many writers of the local geological conditions of sedimentation necessary for the development of a petroliferous series has led some investigators to the conclusion that the conditions of sedimentation may be more influential as a factor in determining oil accumulation than the distribution and character of the structures developed in the particular region. W. F. Jones in a recent paper* has attempted to show that the distribution of the oil pools in Pennsylvania and Oklahoma is more directly related to initial conditions of sedimentation than to the subsequent distribution of structure, and that the accepted favorable structures may be relatively unimportant in determining the accumulation of petroleum as compared with the original basins of accumulation. Certain of Mr. Jones' conclusions are:

1. "No wide lateral movement of oil has taken place and the present position and shape of oil pools closely conforms to the underlying or overlying source of supply."
2. "The areas of supply are lagoonal areas close to and generally parallel with the coast line at the time of deposition."
3. "Pools generally occur in alignment corresponding to the coastal lagoonal areas, each line of pools corresponding to successive shore lines, with generally barren belts intervening."
4. "Larger pools are elongated to correspond to the prevailing elongation of the larger basins of accumulation."
5. "Certain types of structure are favorable for large initial yield of oil, since domes, if they happen to exist in a productive area, act as pressure traps for gas."
6. "Oil pools, in Pennsylvania and Oklahoma, may be largely of predeformational accumulation.
7. "A study of the paleography and a delineation of

* The Relation of Oil Pools to Ancient Shore Lines, by Wm. F. Jones, Econ. Geo., Vol. 15, pp. 81-87, 1920.

ancient shore lines would prove of considerable value in directing the major drilling developments."

8. "There may be extensive areas of favorable oil land in regions condemned at present because of the lack of so-called favorable structure."

While it is undoubtedly true that the delineation of the present pool is greatly influenced by the location of the source of supply, yet it must be kept in mind that the vast majority of the oil pools of Oklahoma (as a type region) are directly related to structures that have been recognized as favorable for oil accumulation. Hager concludes,* from the tabulation of all the principal pools of Oklahoma and some in Kansas that:

1. "Of the 75 pools listed, which comprise the principal pools of Oklahoma and a few in Kansas, all but four are on well-defined structure."

2. "It will be seen that by far the greater proportion of the representative fields listed are of the dome or anticlinal type. Terraces come next in order, while lenses form a small minority. Of the list 45 pools, or 60 per cent., are on domes and anticlines; 15 pools, or 20 per cent., are on terraces, and 11 pools, or 14.7 per cent., are undivided, while 4 pools, or 5.3 per cent., are on lenses. If those fields on undivided terraces and domes (14.7 per cent.) are split equally, which is fair enough, then 7.35 per cent. will be added to the dome, and to the terrace list; so that 67.35 per cent. are on domes and anticlines, 27.35 per cent. are on terraces, and 5.3 per cent. on lenses, which is a fair ratio for the Mid-Continent fields."

3. "Also, it is interesting to note that of 45 pools found in 1913 and later, 30 pools, or 66 2/3 per cent., have been opened by the geologists—a truly remarkable record. Of these the geologists have credit for but one terrace."

More recent work by K. C. Heald shows that over 88 per cent. of the anticlines and domes of the Osage Nation are oil bearing as compared with about 15 per cent. of the synclines. The impartial observer, therefore, is forced to the conclusion that even though the distribution of the petroliferous formations comprising the source of the oil necessarily determines the larger outlines of the oil-producing

* Evidence of the Oklahoma Oil Fields on the Anticlinal Theory, by Dorsey Hager, Trans. Am. Inst. Min. Engrs., Vol. 56, pp. 843-846, 1916.

areas, yet the local accumulations in the known pools have been so conclusively demonstrated to be related to and dependent upon structure, that one inevitably concludes that the factor of structure still remains the most important in the forecasting of petroleum-producing areas.

THE GEOLOGICAL DISTRIBUTION OF OIL.

Commercial production was first found in this country in the Carboniferous strata of Pennsylvania, and subsequently large production has been obtained from several younger formations. Some time ago it was the popular idea that oil would not be found in sediments older than the Carboniferous. At that time there was thought to be an intimate connection between oil and coal formation, and since no coal is found below the Carboniferous it was reasoned that oil would likewise be restricted to that and younger formations. This idea caused many operators to hesitate in developing areas underlain by formations older than the Carboniferous. We have seen, however, that there is no connection in origin between oil and coal and that the conditions which we now consider essential for oil formation and accumulation did exist during several of the geologic periods prior to the Carboniferous. These points have now been proven by the discovery of oil in large quantities in the Trenton (Ordovician) formation and in lesser quantities in the Devonian and Silurian strata. We may expect the formation of oil, therefore, in formations of any geological age, when the conditions are ripe for the preservation, in an environment free from oxygen, of abundant marine organisms. In this country the most prolific horizons are the Carboniferous, Cretaceous and Miocene, with lesser production from the Ordovician, Silurian, Devonian, Eocene, Oligocene and Pliocene. Up to the present time no commercial quantities of oil have been found in the Cambrian or older formations, and even though there is widespread evidence of abundant marine life in the seas of these early periods it is hardly probable that important accumulations will be found in these sediments, for they have been subjected almost universally to much disturbance and deformation and in addition have lost much of their oil content by evaporation during the enormous periods of time that have elapsed since their deposition.

THE GEOGRAPHICAL DISTRIBUTION OF OIL.

The geographical distribution of oil is a subject now attracting much of the attention of petroleum geologists and operators. Since the development of recent ideas regarding the origin of oil and the geological conditions necessary at the time of sedimentation, geologists are beginning to acquire more comprehensive ideas as to the areas of the earth's surface where oil will be most likely found, and other areas where the conditions are impossible for its formation and accumulation.

In a recent paper Woodruff* has outlined some of the factors that will control the geographical distribution of oil. Those areas in which the formation and accumulation is possible he has termed *petroliferous provinces*, and in North America he has outlined such provinces as follows:

1. In Western Alaska. Oil seeps are known in this province; there has been some drilling but as yet no considerable production.

2. In Western Canada from the Arctic Ocean to and including Montana. Some commercial production may be found in the northern part of this province; the southern part is of doubtful value.

3. Along the Pacific Coast in California, Oregon, and Washington. Only the southern part of this province seems important.

4. In Wyoming, Colorado, and a part of New Mexico. Only small areas in this province will be productive.

5. In Oklahoma, Texas, and Louisiana. Considerable areas in this province are productive and others will probably be found.

6. From Pennsylvania to and including Illinois and extending southward into northern Alabama and Mississippi.

7. In Lower California. This province seems of doubtful value but may be productive.

8. On the eastern coast of Mexico.

Commenting upon the delineation of the petroliferous provinces by Woodruff, Shuchert** has suggested that the petroliferous and non-petroliferous rocks of any continent

* E. G. Woodruff: Petroliferous Provinces, Mining and Metallurgy, No. 150, pp. 907-912, June, 1919.

** Op. Cit., p. 3059.

be determined by the application of the following principles:

1. The impossible areas for petroliferous rocks.

(a) The more extensive areas of igneous rocks and especially those of the ancient shields; exception, the smaller dikes.

(b) All pre-Cambrian strata.

(c) All decidedly folded mountainous tracts older than the Cretaceous; exceptions, domed and block-faulted mountains.

(d) All regionally metamorphosed strata.

(e) Practically all continental or fresh-water deposits; relic seas, so long as they are partly salty, and saline lakes are excluded from this classification.

(f) Practically all marine formations that are thick and uniform in rock character and that are devoid of interbedded dark shales, thin-bedded dark impure limestones, dark marls, or thin-bedded limy and fossiliferous sandstones.

(g) Practically all oceanic abyssal deposits; these, however, are rarely present on the continents.

2. Possible petroliferous areas.

(a) Highly folded marine and brackish water strata younger than the Jurassic, but more especially those of Cenozoic time.

(b) Cambrian and Ordovician unfolded strata.

(c) Lake deposits formed under arid climates that cause the waters to become saline; it appears that only in salty waters, (not over 4 per cent.?) are the bituminous materials made and preserved in the form of kerogen, the source of petroleum; some of the Green River (Eocene) continental deposits (the oil shales of Utah and Colorado) may be of saline lakes.

3. Petroliferous areas.

(a) All marine and brackish water strata younger than the Ordovician and but slightly warped, faulted, or folded; here are included also the marine and brackish deposits of relic seas like the Caspian, formed during the later Cenozoic. The most certain oil-bearing strata are the porous, thin-bedded sandstones, limestones, and dolomites that are interbedded with black, brown, blue, or green shales. Coal-bearing strata of fresh-water origin are excluded. Series of strata with disconformities may also be petroliferous,

because beneath former erosional surfaces the top strata have induced porosity and therefore are possible reservoir rocks.

(b) All marine strata that are, roughly, within 100 miles of former lands; here are more apt to occur the alternating series of thin and thick-bedded sandstones and limestones interbedded with shale zones.

FACTORS DETERMINING THE GEOGRAPHICAL DISTRIBUTION.

The Character of the Sediments.—It is apparent, therefore, that the prime factor determining the geographical distribution of petroliferous areas is the lithologic character of the rocks involved. Only the sedimentary areas need be considered, and of the sediments those formed under subaerial conditions of land deposition can be eliminated as well as those rarely encountered marine sediments formed in the deeper portions of the ocean. It is between these two regions in the areas adjacent to the ancient shore lines, existent at the time of deposition, that the geologist should devote his closest attention. The importance of these former shore lines has been for some time recognized by geologists but no concerted action has been taken in regard to outlining and mapping in detail these areas of greatest significance.

The Nature of the Reservoir.—We have seen that only a minute fraction of the areas termed petroliferous provinces actually produce oil in commercial quantities. This is chiefly due to the lack of adequate structural traps to prevent the oil migrating to the surface and there being lost. Still in petroliferous areas there are many well-defined and favorable structures that are non-productive. The causes for such non-productivity have in some cases never been discovered. Local changes in the original conditions of sedimentation; leakage points in the structure in depth, not expressed upon the surface; age of the folding that gave rise to the structure as compared with the age of the sediments themselves; all such causes may separately or in conjunction prevent accumulation even when other factors are favorable.

In addition there is the question of local efficiency of the reservoir in bringing about the accumulation. We have seen

that sandstones are among the most porous of rocks and make the best reservoirs. If, however, the sandstone has been secondarily cemented by the action of circulating siliceous waters in the area where favorable structure has been formed, resulting in the reduction of pore-space to the minimum, the value of the rock as a reservoir will be much diminished and no large accumulation will take place. Or, if at the time of sedimentation the conditions that brought about the deposition of a coarse-grained sandstone were changed and mud as well as sand were locally deposited, in this locality the resultant sediment would be a shaly sandstone of very little pore-space and of little value as a reservoir. Local thinning in the sandstone or the development of "partings," local wedges of shales and other non-porous sediments, may also detract from the value of the reservoir.

Metamorphism.—The effect of metamorphism on the distribution of oil had not been fully appreciated until David White formulated the carbon ratio theory. The substance of this theory will be given more fully under a subsequent heading. In main, however, it postulates that in areas where deformation and resultant metamorphism have occurred to such an extent that the fixed carbon in the coals of the same area runs as high as seventy per cent., calculated upon a pure coal basis, it is extremely improbable that any important accumulation of oil will be found. This criterion is obviously only applicable to those sedimentary areas where both carbonaceous and petroliferous sediments occur.

Climate.—If one studies the distribution of the important oil fields of the earth's surface he will be impressed with the fact that they seem to be restricted to certain ranges in climate. Mehl* has recently shown that all the more important oil fields lie between 20° and 50° north latitude, and in regions where the present mean annual temperature varies between 40° and 70° F. If subsequent discoveries conform to the same rule there would be suggested some possible relation between oil distribution and climate. The writer, however, can at present see no connection between actual climates and oil distribution, and believes that this apparent zonal arrangement is largely due to accident. The climates of the past, on the other hand, have been

* M. G. Mehl: Some Factors in the Geographical Distribution of Petroleum, Bull. Sci. Lab., Denison Univ., Vol. 19, pp. 55-63, 1919.

shown to be of prime importance in the development of abundant life and would consequently be among the determining factors in the distribution of the petroliferous areas.

THE FIELD WORK OF THE GEOLOGIST.

The geologist in making field examinations must have several points in view. In the first place he must determine by the evidence of the fossils or by any other means he may have the relative position of the sediments, with which he has to deal, in the geological column. In many cases the age of the formation has been determined by previous workers, but in wholly undeveloped regions it often happens that the geologist must rely wholly upon his own investigations to obtain all data necessary to enable him to draw correct conclusions. In such cases he must first determine the age of the formations, then make a careful study of the nature and origin of the sediments in which he hopes to find oil. This can only be done at points where the strata in question are exposed, and the exposures may be separated from the areas of favorable structure by considerable distances, so there enters the question of correlation between the points of exposure and the site chosen for a test. In examining the formations involved, or what is termed the local geologic section, the geologist must measure carefully each distinct formation and make careful note of its lithologic character in order to determine its possibilities as a petroliferous series; he must seek, measure and examine minutely all formations that could be considered as possible reservoirs; he must locate these with respect to the other formations of the section; and to the best of his ability forecast their depth at the point he has chosen for his first test well. For example, consider a test being made in Monroe County in the southern part of the State. In this area the objective or possible pay horizon might be the Tuscaloosa formation, unexposed except almost a hundred miles to the north. The geologist must therefore, consider this formation where exposed and from this examination, aided by his general fund of geological knowledge draw his conclusions as to its depth and character in Monroe County. Its depth he can determine from the average dip of the other strata exposed in the intervening area; its character he has determined at the point of outcrop to be decidedly unfavorable for an oil-

producing series. However, he knows that the Cretaceous shore line roughly approximated the southern boundary of the Tuscaloosa formation as exposed at present and as one continued southward in this Cretaceous sea conditions should become more and more similar to those necessary for oil formation. Therefore, he infers that the Tuscaloosa formation as developed a half mile below the surface in Monroe County might readily be a marine formation with all the requirements of a petroliferous series. Naturally he cannot prove these surmises without making a test, and he may recommend that a test be made for he logically reasons that the series presents good chances, while if he had known nothing of the local geological conditions in Cretaceous times, he may have inferred that the Tuscaloosa formation retained its same character to the south and so would be worthless as a producing horizon (Fig. 9).

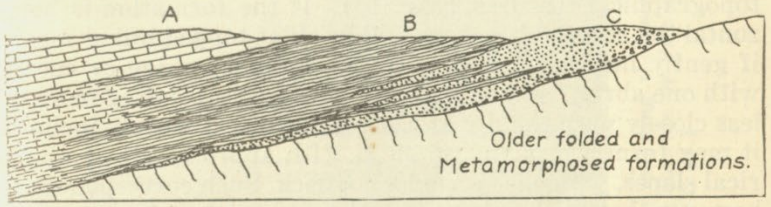

FIG. 9. Generalized section of the coastal-plain of Alabama showing (C) the Tuscaloosa formation, a typical continental formation, grading into a marine series in the direction of the early Cretaceous sea, and (B) the Eutaw shales and sands grading into marine shales and shaly limestones, and finally (A) the Selma Chalk, a marine formation representing a period of comparatively deep and clear water conditions of deposition in later Cretaceous time. This is a hypothetical set of conditions, which if true would greatly increase the possibilities of oil production from the Tuscaloosa and Eutaw formations in southern Alabama.

In addition to the interpretation and correlation of the section the geologist must seek localities where the structure is favorable for the accumulation of oil, that is, localities where the strata have been folded into anticlines, synclines, domes and basins. This he must do by the careful mapping of the area and the plotting of all the exposures and the direction of the dip in every instance. In certain regions the formations are so well exposed that he can trace a single stratum all over the area he plans to map. This he considers his key bed and by the use of the plane-

table and telescopic alidade he determines and maps the elevation of the bed at many points. He then draws contours based upon these elevations by which he portrays the structure of the key bed exactly as a topographic map portrays the character of the surface of the ground. (Fig. 2).

Structural Features and Topographical Features.—In this connection one must clearly distinguish between structural and topographical features. Sometimes there may be a relationship between the two, but more often they are wholly independent. It more frequently happens that an anticline, especially when it is a pronounced fold, is represented by a valley than a ridge. Jones Valley and Brown's Valley are both anticlines, and on the other hand, synclines are often represented by ridges or areas of relief. Hard resistant formations may sometimes stand out as distinct topographical features (Fig. 10). If the formation is horizontal the resultant feature will be a flat-topped hill or mesa; if gently inclined it may form an extended ridge or cuesta with one abrupt and one gentle slope, corresponding more or less closely with the dip of the formation; if steeply inclined it may form a pronounced ridge with approximate symmetrical slopes, which is termed a hogback. Such correspondence however, between topographical and structural features is the exception rather than the rule, usually there being no indication of the structures, as determined by plotting of the dip and strike at many points, in the topography of the area.

THE SURFACE INDICATIONS.

We see, therefore, that the geologist does not base his conclusions upon surface indications, except in so far as the exposures indicate the structure of the underlying formations. He realizes that the formation that happens to form the surface in the area under consideration may be wholly dissimilar to the concealed formation that he considers a possible oil horizon. There are, however, certain indications that may impress the geologist either favorably or unfavorably in drawing his conclusions.

Oil and Gas Seeps.—The most important of the favorable indications is the occurrence of definite oil or gas seeps in the area under consideration. If there are actual seeps

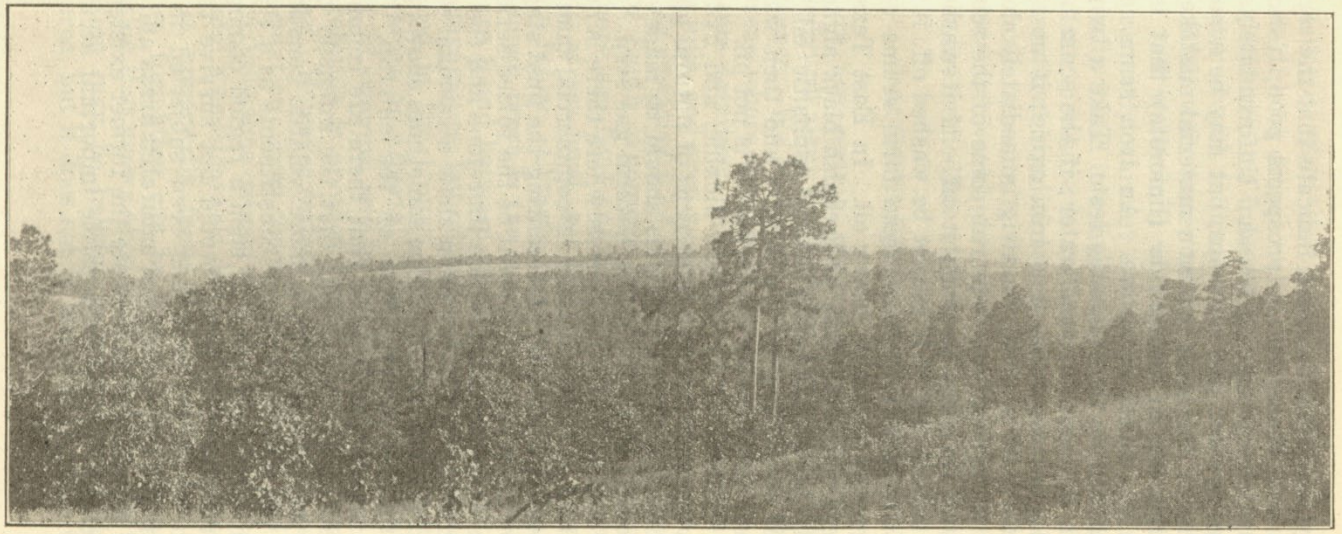

FIG. 10. The Aldrich Dome southeast of Birmingham showing the relation of structure to topography. The capping sandstone is the Millstone Grit while the upper conglomerate or Pine sandstone completely encircles the structure, forming an infacing escarpment. (Courtesy T. H. Aldrich, Jr.)

in the locality they would at least indicate that the series is petroliferous, and therefore the prospects good, if well-defined structural traps can be found. Unfortunately most reported seeps are not real oil seeps, but may be a number of other things. The most common material mistaken for oil scum is the film of iron oxide (limonite) that is frequently seen on stagnant waters. An iron scum can be readily recognized by the following test: Take a twig and immerse it in the scum-covered water; if the scum breaks up and cracks develop in it, it is iron oxide; if no cracks develop and the hole made by the twig immediately closes it may be oil. A further test is to rub some of the scum on the fingers and then try to wash it off. If it washes off readily it is not oil, but if it cannot be washed off, it probably is oil. In certain regions algae form scums on the water that greatly resemble heavy oil. In East Texas the writer has seen scums of black or greenish black algae that would readily be mistaken for heavy asphaltic oil. The simple test of rubbing it on the fingers and then washing it off, however, immediately shows that it is not oil.

Likewise bubbles of air, carbon dioxide, and hydrogen sulphide may be mistaken for true seeps of natural gas. A combustion test or chemical analysis should be made of the material before it is pronounced a natural gas seep.

In highly folded and faulted areas where there is no possibility of oil or gas accumulation in commercial quantities oil and gas seeps may occur, representing the final stages in dissipation of the petroleum content of the folded series. In Alabama, for example, the Trenton limestone and the Knox dolomite in the Coosa Valley region show occasional oil and gas seeps and the Trenton limestone sometimes shows petroleum saturation or impregnation on the outcrop. These shows, however, do not indicate that there are commercial deposits of oil or gas below, but that the intensity of the deformation has driven off the more volatile constituents leaving only the heavier asphaltic constituents as a residual impregnation at the surface. In such a region commercial pools though formerly present, would not survive the deformation to which the area has been subjected in later geologic time, and only occasional saturated areas and seeps remain until the present to indicate the former existence of greater petroleum content or possible important accumulations.

Salt Water Wells and Artesian Wells.—Strong flows of salt water in the deeper wells of any locality may be considered an unfavorable indication as the presence of abundant salt water would indicate that the reservoirs were completely filled with water to the exclusion of oil. A strong flow of salt water in a well drilled on favorable structure would certainly warrant such a conclusion. Artesian wells are usually found in synclines and structural basins, where hydrostatic pressure is sufficient to cause a flowing well. The structural conditions necessary to artesian flow are in the main opposite to those necessary to oil accumulation. Therefore one would not expect to find favorable oil structures in the immediate vicinity of artesian wells.

FACTORS OF NO SIGNIFICANCE.

There are certain phenomena sometimes erroneously considered oil signs by the laity, but which in fact have no significance. We have seen that topography, except in certain areas where the dip slope can be seen, is no index to petroleum territory. Oil fields occur beneath flat plains, rolling hills, and even rugged and mountainous topography. Likewise elevation is of no significance. In the Rock River field of South Wyoming the oil-bearing horizon is 5,000 feet above sea level and at Goose Creek, Texas, the wells starting at sea level, get their production from 3,000 feet or more below. Climate is also unrelated to oil territory, even though there is the suggestive fact that the major oil fields are found between certain limits in latitude and annual temperature, but oil fields of less importance have been developed in the tropics and in the comparatively frigid temperature of Alberta. Likewise they are to be found in deserts, in swamps, and in fertile plains.

Vegetation is another factor of no significance strictly speaking. However certain rock types can be recognized by the vegetation upon them. In north central Texas, for instance, limestone-capped hills can be readily recognized as such from a considerable distance by the mesquite and live oak that apparently favor the limestone soil. In other localities formation can be traced great distances by the vegetation that grows upon their outcrops. In this way the vegetation may be helpful in working out the structure of an area, but it does not in any way indicate the presence

or absence of oil in the underlying sediments. Other factors of no significance are the kind of surface rock, the abundance or scarcity of certain colored pebbles, or any other kind of loose material, shells, fossils, and so forth. All of these features are wholly unconnected and unrelated to the underlying formations in which the oil must occur.

THE VALUE OF GEOLOGICAL EXAMINATION.

The actual value of geological examination has been much disputed by operators, particularly in the earlier days when the geologist knew little regarding the conditions necessary for the origin and the many factors that influence the accumulation of oil. With the development of modern ideas and theories, which have been in great part proven by actual experience, the expediency of a preliminary geological examination has been more and more appreciated by the far-sighted operators, and at present practically every large and progressive oil company has an established geological department and a corps of geologists. Indeed at present the petroleum geologist depends solely on the operators for employment, as the land owner is not yet educated to the value of a geological examination and is unwilling to pay the necessary cost. It is not the excitable land-owner that is willing to pay the comparatively high fees of the consulting geologist to determine the value of his land, but the hard-headed operator, whose common sense shows him that the cost of geological examination is negligible as compared with the cost of a test, and if it in any degree increases the possible chance of success it is well worth while.

Unfortunately in Alabama, as in many other wildcat territories, much money has been wasted by lack of intelligent geological advice. Though numerous wells have been sunk in all parts of the State only three or four have been located upon the recommendation of reputable geologists. Undeveloped territory is the playground of the promoter whose chief object is the mulcting of the natives, and whose last idea would be the conscientious development of producing territory. The future, however, is more promising. Large companies are entering the field and the locations of future tests will be determined upon the evidence obtained by exhaustive and detailed geological study.

THE OUTLOOK IN ALABAMA.

On the whole the future prospects for Alabama are promising. There occur in certain parts of the State sediments that meet all the requirements for oil production and a variety of favorable structures occur throughout many parts of the State, which should bring about the accumulation of the oil originating in the petroliferous strata. In these series are also found formations, some of which have a high percentage of pore-space, and which should make good reservoir rocks. So it can be seen that it simply remains to find these localities where all the conditions are favorable and there make sufficiently deep tests. In the past only one or two such tests have been made, so the failures of the past should be no discouragement for the future.

Geologically Alabama is readily subdivided into three provinces; in the first of which oil accumulation in commercial quantities would be impossible; in the second such accumulation would be very improbable; and in the third commercial accumulation would be possible, and in certain favorable localities even probable.

Impossible Area.—In the following counties commercial accumulation of oil is considered impossible:

Chambers,
Chilton,
Clay,
Cleburne,
Coosa,
Elmore,
Lee,
Randolph,
Tallapoosa,
Talladega (in part).

Improbable Area.—In the following counties, lying in the areas where the chance for commercial production is very improbable, it would not be wise to spend money in prospecting:

Autauga,
Barbour (in part),
Bibb,
Blount,
Bullock,
Calhoun,
Cherokee,
Dallas,
DeKalb,
Etowah,
Greene,
Hale,
Jackson,
Jefferson (in part),
Limestone (in part),
Lowndes,
Macon,
Madison (in part),
Marengo (in part),
Marshall,
Montgomery,
Perry,
Pickens,
Russell,
Shelby,
St. Clair,
Sumter,
Talladega.

The following counties should also be classified with improbable territory, because loose gravel and other unrelated surface formations completely conceal the petroliferous strata below, making it impossible to determine the geological structure of these areas:

Baldwin (in part),
Lamar (in part),
Mobile,
Pickens,
Tuscaloosa (in part).

Possible Area.—The counties in which production is possible are the following:

Baldwin (in part),
Barbour (in part),
Butler,
Choctaw,
Clarke,
Coffee,
Colbert,
Conecuh,
Covington,
Crenshaw,
Cullman,
Dale,
Escambia,
Fayette,
Franklin,
Geneva,
Henry,
Houston,
Lamar (in part),
Lauderdale (in part),
Lawrence,
Marengo (in part),
Marion,
Mobile (in part),
Monroe,
Morgan,
Pike (in part),
Tuscaloosa (in part),
Walker,
Washington,
Wilcox (in part),
Winston.

THE GEOLOGICAL PROVINCES OF ALABAMA.

The subdivision of the State of Alabama into the three provinces given above; namely the impossible territory, the probable territory and the possible territory, is based upon the nature of the geological formations developed in each province. This classification can be carried a step further and the State subdivided into eight distinct provinces in each of which the geological conditions are either slightly or entirely dissimilar, giving rise to eight territories in which the possibilities for oil and gas would vary according to the nature and structure of the rocks involved. On the accompanying outline map of the State (Fig. 11) these provinces are shown. As can be readily recognized the boundaries of the provinces usually roughly coincide with boundaries of the different geological formations. In some cases, however, the boundaries follow changes in structure rather than differences in the age of the formations. Moreover, as the subdivision of the State into these provinces is purely from the point of view of possible oil and gas production

the boundary lines are indefinite and even though they generally correspond with those of the geological formation they do not necessarily do so.

Province One.—Impossible territory. The crystalline area composed of rocks of pre-Cambrian age in most parts, which are so highly metamorphosed that neither oil nor gas accumulation is possible.

Province Two.—The Paleozoic area of highly folded and faulted sedimentary rocks, extending as far northwest as the sixty-five per cent. isovolve (Fig. 15), and southwest until overlapped by the Cretaceous formations. This area represents the southern end of the folded Appalachian mountains, and it can be considered as an extremely improbable territory for oil accumulation. The accumulation of gas, however, is possible, and the development of small pools can be expected throughout the more favorable portions, from a structural standpoint, of the entire area.

Province Three.—The Plateau Region and the Tennessee Valley; a province of approximately horizontal or gently warped Paleozoic sediments comprising a petroliferous series in which there are four or five distinct potential oil and gas horizons. This area is probably the most favorable for oil and gas production that is to be found in the State. The situation of this province near the top of the Cincinnati Uplift is an additional favorable feature.

Province Four.—That portion of the Plateau Region where the petroliferous series, that is, the Paleozoic sediments, is concealed by the unconformable cover of the gravels and clays of the Cretaceous formations, so that it is impossible for the geologist to determine the structure of the formations in which the oil if present will occur. The eastern boundary of this province is indefinite, as in this area the Cretaceous sediments cover the upland areas while the Paleozoics are exposed along the streams. The possibilities for oil and gas accumulation in this province are the same as in number three, but owing to the additional cover drilling will have to be continued deeper and prospecting carried on by wildcatting, strictly speaking.

Province Five.—Impossible territory. That southernmost tip of the folded Appalachian mountains which is covered by the overlapping Cretaceous strata. This province is considered impossible territory because the petroliferous series, the Paleozoic formations, are not only intensely

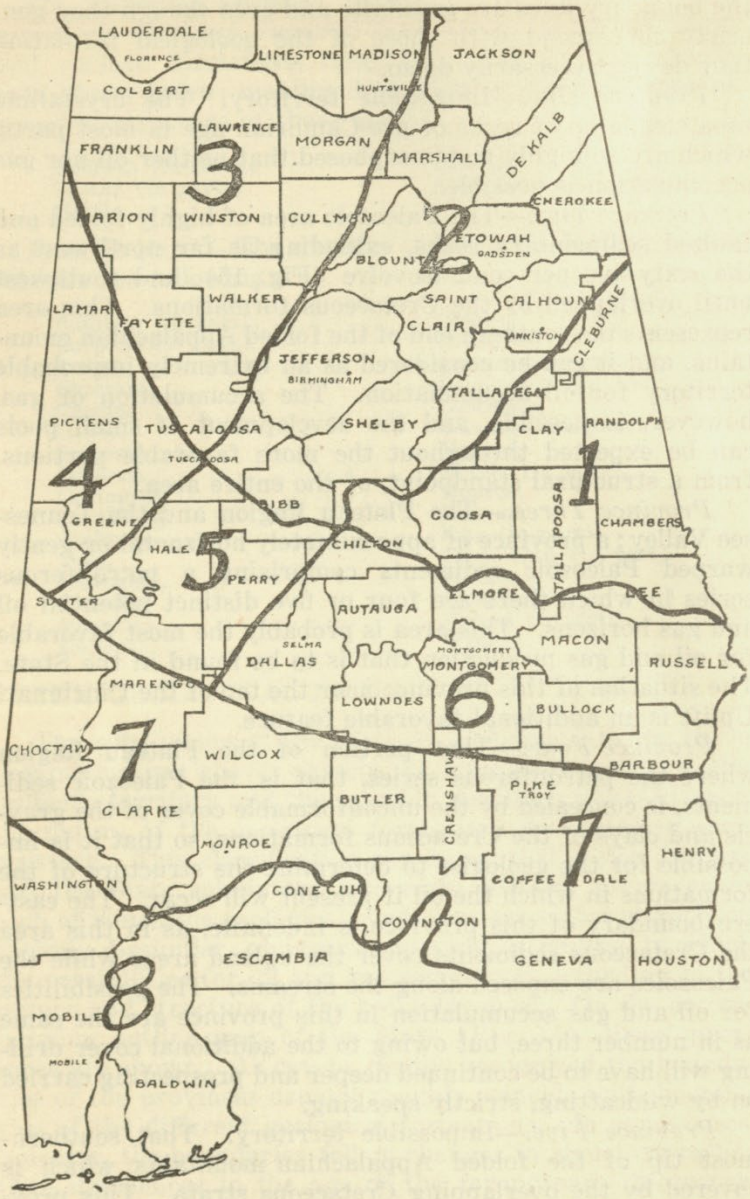

FIG. 11. Outline map of Alabama showing the eight geological provinces. Provinces 3 and 7 constitute the more probable oil-producing territory of the State.

folded and faulted but are wholly concealed by an unconformable cover.

Province Six.—Impossible territory. The metamorphic rocks of the crystalline area (province 1) which are covered by the overlapping Cretaceous formations. As the Cretaceous formations in this province do not show the characteristics of a petroliferous series where sufficiently covered to entrap oil they can be eliminated as a possible oil producing series, and beneath them in the crystalline rocks oil accumulation is likewise impossible.

Province Seven.—A region of Tertiary sediments dipping gently to the south and overlying conformably a series of Cretaceous formations, which as developed in depth in this province show many of the characteristics of petroliferous series. The Cretaceous series is of marine origin and is locally folded so that structures favorable for the accumulation of oil and gas are developed, and these structures can be recognized as such by the geologist making an examination of the area. It is possible, however, that these sediments contain insufficient animal and plant remains to generate commercial quantities of petroleum. This province together with province 3 comprises the favorable oil territory of Alabama.

Province Eight.—A region in which the geological conditions are the same as in province 7, except that the petroliferous series is more deeply buried (2,000 to 5,000 feet), and the surface is formed by unconsolidated material, so that the geologist is unable to locate definite structure and development must be brought about by wildcatting.

GEOLOGICAL CROSS-SECTIONS OF NORTH ALABAMA.

The valuable and instructive cross-sections that were made by Henry McCalley some time ago to accompany his Report on the Valley Regions of Alabama have been reproduced for this report (Plate II inside back cover). These cross-sections, on account of their accuracy and great detail, should be of inestimable value to the future prospector as well as the landowner in giving them at a glance the general features of the structure in all parts of northern Alabama. On the accompanying index map (Fig. 12) the locations of the sections that are referred to by number on

Plate II are given. At the time the manuscript was written the reproduction of these sections was not contemplated, and so reference to them in the text has not been made so frequently as their real value would warrant.

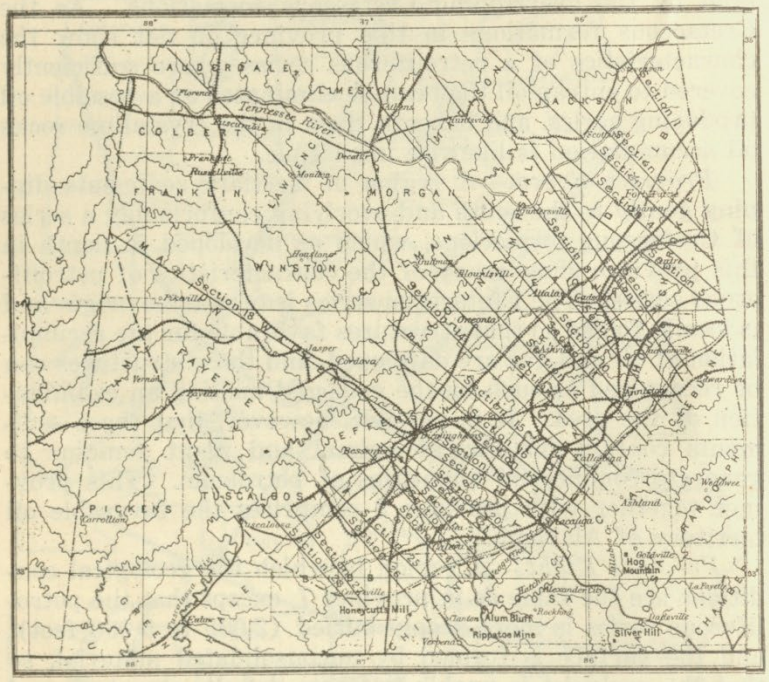

FIG. 12. Index map of Northern Alabama showing the locations of the sections shown on Plate II (in pocket inside back cover).

ACKNOWLEDGMENTS.

The writer wishes to acknowledge his indebtedness to the many who have contributed information, suggestions and well logs that have added to the completeness of this report. He is especially grateful to the State Geologist, Dr. Eugene A. Smith, for much helpful information regarding the geology of the State; to Dr. Stewart J. Lloyd, of the University of Alabama, formerly Inspector of Oil and Gas Wells, for the use of numerous well logs; to Mr. S. A. Hobson, of Birmingham, for many logs and helpful information regarding the past development in the State; to Dr. R. M.

Harper, Geographer of the Geological Survey, for helpful criticism and proof-reading; to Mr. R. S. Hodges, Chemist of the Geological Survey, for numerous analyses of coal and oil, and to Mr. W. B. Jones, of the University of Alabama, for assistance in the field work.

The writer is likewise indebted to the various companies and other individuals that have so kindly supplied the locations, logs and results of the wells that have been drilled and are being drilled throughout the northern part of the State.

PART I

NORTHERN ALABAMA*

THE possible oil territory of Alabama can be readily divided into two regions, the Paleozoic area of the north,** and the Coastal Plain province of Cretaceous and younger formations lying to the south. These two provinces will be treated separately in the present bulletin. The northern province will first be discussed as a whole and then by counties.

Topographically, as well as structurally, the Paleozoic area can be divided into three rather well-defined provinces: (1) The broad, open Coosa Valley lying adjacent to the crystalline oldland, with comparatively little relief, except for occasional longitudinal ridges and rather intense folding; (2) the plateau region of horizontal or gently warped Pennsylvanian strata broken by occasional anticlinal valleys aligned northeast and southwest, outliers of the Coosa Valley proper, in which the older Paleozoic formations are exposed—a region of much relief (200 to 300 ft.) and thorough dissection, well wooded, and of little agricultural impor-

* In the discussion of the general features and oil possibilities of this area the writer has drawn freely from a paper recently published by him and quoted below.

** Among the more important references on the geology, physiography, and economic resources of northern Alabama are:

Henry McCalley: Natural Gas and Petroleum in North Alabama. Proc. Ala. Industrial and Scientific Soc., Vol. 1, No. 1, pp. 35-48 (1891).

Henry McCalley: Report on the Valley Regions of Alabama. Part 1, The Tennessee Valley Region; Part 2, The Coosa Valley Region. Geological Survey of Alabama (1896).

Henry McCalley: Report on the Coal Measures of the Plateau Region of Alabama, Geol. Survey of Alabama (1891).

Henry McCalley: Report on the Warrior Coal Basin, Geol. Survey of Alabama (1900).

M. J. Munn: Reconnoissance Report on the Fayette Gas Field, Alabama. Geol. Survey of Alabama, Bull. 10 (1911). Also published under the title: The Fayette Gas Field, Alabama. U. S. Geol. Survey, Bull. 471, pp. 30-55 (1910).

R. M. Harper: Economic Botany of Alabama. Part I, Geol. Survey of Alabama (1913).

Eugene A. Smith: Historical Sketch of Oil and Gas Development in Alabama. Oil Trade Journal, Vol. 9, p. 133 (April 1918).

D. R. Semmes: Oil Possibilities in Northern Alabama, Min. & Met., No. 159 (March, 1920).

tance; and (3) the Tennessee Valley region of horizontal or gently warped Pennsylvanian and Mississippian strata, where the relief is not so marked, the wooded area is less extensive, and the country is of more importance agriculturally.

STRATIGRAPHY.

The following generalized section gives an approximate idea of the thickness and lithologic character of the formations of the region as a whole. The Carboniferous series, especially, shows lateral variations of striking prominence, but certain horizons are persistent throughout the area.

STRATIGRAPHIC SECTION FOR NORTHERN ALABAMA

Age	*Formation Name*	*Thickness*	*Lithologic Character and Subdivisions*
Pleistocene Pliocene	Lafayette	0– 50	Unconsolidated and semiconsolidated gravels and sands. Red, pinkish, maroon, and whitish clays.
Cretaceous	Tuscaloosa	0–1000	Gravels, sands, and clays. Red to gray or white. Non-marine.
Pennsylvanian	Coal measures	200–2500	Shales, arenaceous shales, massive sandstones, and conglomerates near base. Basal conglomerate, or Millstone grit. Coal seams.
Upper Mississippian	Mountain limestone	400– 900	Massive bluish crinoidal limestone (Bangor limestone), overlying a series of coarse to medium-grained sandstones with alternating thinner beds of limestones and shales. Thick, locally massive, brown sandstones at base (Hartselle sandstone).
Lower Mississippian	Fort Payne chert	200– 500	Cherty limestone or limestones with thin chert seams or layers of nodules. Readily eroded, valley-making formation (Tuscumbia limestone). This overlies a series of hard cherts (Lauderdale chert), very resistant to erosion and forming prominent ridges.
Devonian	Black shale	0– 50	Black, highly bituminous shales and locally thin sandstones and bluish shales.

FIG. 13. Extensive gully formation in the Tuscaloosa clays, (near Saunder's Ferry, Tuscaloosa County), which cover the Coal Measures along the northwestern line of the State. (Photo by R. M. Harper.)

Age	*Formation Name*	*Thickness*	*Lithologic Character and Subdivisions*
Silurian	Clinton	200– 400	Shales, limestones (Niagara), and ferruginous sandstones and some conglomerates. Iron ores.
	Unconformity (?)		
Ordovician	Trenton limestone	500–1000	Bluish, thin-bedded limestone (Pelham or Chickamauga) with coarse-grained siliceous layers, making excellent oil sands.
	Unconformity		
	Knox dolomite	2000–3300	Sharply folded and faulted thick-bedded crystalline dolomite with chert seams, overlying 600 ft. of thick-bedded non-cherty gray crystalline dolomite.
Cambrian	Coosa shales	1000–1500	Thin-bedded blue limestone and gray and yellow shales.

Of these formations the Carboniferous formations cover much of the larger part of the whole region, the Pennsylvanian, or Coal Measures, forming the surface throughout large portions of Cullman, Winston, Walker, Blount, Jefferson, and Tuscaloosa Counties, and the Mississippian forming the surface in Madison, Limestone, Lawrence, Lauderdale, and Colbert Counties. To the west, the Carboniferous strata are overlapped by the Cretaceous, which in turn is covered in places by the Lafayette, but throughout a large part of this Cretaceous area the underlying Coal Measures are exposed along the courses of the principal streams. The pre-Carboniferous rocks are only exposed in small areas in the north, along the anticlinal valleys farther south, and in the Coosa Valley.

OIL AND GAS HORIZONS.

The possible oil and gas horizons throughout the section are rather numerous; many of these horizons have, locally, given very promising shows. Owing to the striking lateral variations in lithologic character, horizons that may at one point be promising have little or no possibilities at another; this is especially true in the Carboniferous series.

Pennsylvanian Horizons.

In the Fayette gas field in Fayette County, the wells encountered the first shows at about 500 feet (152 m.) below

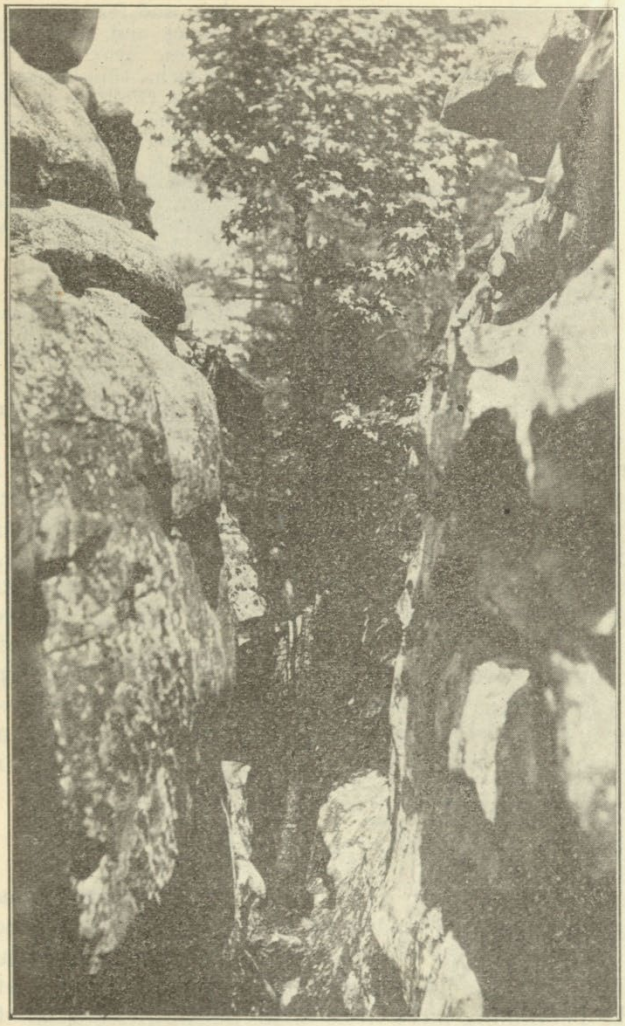

FIG. 14. Crevices in the Millstone Grit (Eight-acre Rock, Tuscaloosa County) showing the massive character of this formation. The sandstone as a whole is a poor oil horizon, but porous horizons in it may prove productive. (Photo by R. M. Harper.)

sea level, or at a depth of from 850 to 950 ft. (259 to 289 m.). This sandstone, though giving good shows of oil, proved of no value and the wells were continued 500 ft. lower and there encountered the Fayette gas sand proper, a soft, white sand of excellent quality. The best well of this group was estimated at 4,000,000 cu. ft. (112,000 cu. m.), per day. At other points, the sand was found more tightly cemented and proved less productive. About 200 ft. below the Fayette sand a thick sandstone (250 ft.) was encountered, which also gave gas shows and is locally known as the Second Gas sand. Drilling has been continued 900 ft. below the Fayette sand and another thick sandstone, containing salt water, was encountered near the bottom. This sandstone has been correlated with the Pine sandstone member of the Birmingham Folio,* in which case the Fayette sand should be underlain by some 1,000 ft. of shales and massive sandstones to the base of the Pine sandstone, then 500 ft. of shales and shaly sandstones, and finally 500 ft. more or less of massive sandstones with conglomerates at the base (Millstone grit). In other words, the Fayette gas sand should be about 2,000 ft. above the base of the Pennsylvanian, if maximum thicknesses were represented. Deep borings in the area have shown, however, that the total thickness of the Pennsylvanian is not over 2,300 ft., or only about 1,000 ft. of sediments underlie the Fayette sand.

The two basal sandstones of the Coal Measures, the upper and lower conglomerates, or the Pine sandstone and the Millstone grit, can be considered as possible oil horizons, but owing to their great thickness, thorough cementation, and massive character, as well as the fact that they have no adequate source of oil below, the writer would not consider them horizons worthy in themselves of extensive testing. (Fig. 14.)

Mississippian Horizons.

As early as 1865, wells were drilled in Lawrence County in the vicinity of asphaltum and maltha showings in Mississippian strata, and the majority of all such occurrences of bitumen, maltha, and asphaltum that have been reported since are in these formations. In the Bangor limestone, many such occurrences have been found and it is not unrea-

* Folio No. 175. U. S. Geol. Survey.

sonable to suppose that a sandy layer in this limestone might prove a paying oil sand. Below the Bangor comes the Hartselle group of thick sandstones and interbedded limestones. In Morgan, Lawrence, and Franklin Counties, numerous seeps have been found in the Hartselle, and, in many places, this group is found saturated with residual petroleum. In many localities this sandstone is coarse-grained and friable, with a large amount of pore space, which should make it an excellent oil sand; but elsewhere it is fine-grained and highly cemented and has so little pore space that it is improbable that it would prove a pay sand. Unfortunately, no good test has been made in this horizon as none of the wells started in the Pennsylvanian has reached this depth, while those started below the Pennsylvanian have usually commenced operations on the Hartselle itself, or immediately above it. The Lower Mississippian Tuscumbia limestone has given rather promising shows in certain recent tests. In it are found sandy horizons that, according to the driller's statement, make excellent oil sands. This limestone gave encouraging shows in the wells at Atwood and Frankfort in Franklin County and also in some of the tests made in Walker and Jefferson Counties. It should be regarded, therefore, as a potential horizon in any test located so as to strike it at a reasonable depth.

Trenton Horizon.

The only well that has struck oil in commercial quantities in Alabama found it in the Trenton (Pelham) limestone. This horizon is, in the opinion of the writer, the most favorable for commercial oil and gas to be found in the northern part of the State. The Trenton series is composed of thin-bedded bluish and shaly limestones, throughout which there are horizons of coarse-grained, sandy limestones making good oil sands.

The Trenton limestone has given shows of oil and gas at many points in the northern part of the State. Besides the Goyer well in Lawrence County, in which commercial production was found in the Trenton, it has given good shows of oil in the well at Hartselle, Morgan County, the Atwood well, Franklin County, the Bryan well, Jefferson County and the Allen well near Florence, Lauderdale County. Good shows of gas were also found in the Trenton in the wells near Hazel Green, Madison County.

KNOX HORIZON.

The Cambro-Ordovician Knox dolomite has occasionally given small shows of gas; and since dolomitization with its attendant shrinkage should indicate increase in pore space and in capacity as a reservoir, this formation has been tested several times in the hope of its proving productive. But, as the Knox lies unconformably below the Trenton and where exposed shows a high degree of deformation, its possibilities for petroleum are so slight as to be unworthy of serious consideration.

The possibilities of the Knox as a gas producer are good throughout the north and northwestern portions of the State. A small show of gas was found in the Knox in the Huntsville well, Madison County, and in the Frankfort well, Franklin County, and in the Haleyville well, in Winston County, the Knox produced some 40,000 cu. ft. of gas per day.

STRUCTURAL FEATURES.

The Coosa Valley region and the adjacent outlying valleys are characterized by a rather intense type of parallel folds, trending northeast and southwest, with which are occasionally associated faults showing displacements as great as 10,000 feet. In many of these folds, the Ordovician formations are exposed and they, consequently, have no possibilities as oil traps. In addition to the northeastern series of prominent Appalachian-type folds, there is a series of undulations running northwest and southeast. These folds, or "waves" as they have been termed by the earlier writers, are sometimes quite pronounced and show a reversal of 100 ft. or more. At the intersection of these undulations quaquaversal structures are formed, such as the Blount Springs dome, which should make excellent oil traps if the oil horizons themselves are not exposed. The intensity of the deformation of this area, however, is considered an unfavorable factor in the development of valuable accumulations of oil.

In the Plateau region, running parallel to the Appalachian folds farther east and south, there is a series of subsidiary undulations, which can be traced out in the beds of the Coal Measures. In this area are likewise developed the series of northwest-southeast waves, and at the intersection

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The Trenton limestone has given shows of oil and gas at many points in the northern part of the State. Besides the Goyer well in Lawrence County, in which commercial production was found in the Trenton, it has given good shows of oil in the well at Hartselle, Morgan County, the Atwood well, Franklin County, the Bryan well, Jefferson County and the Allen well near Florence, Lauderdale County. Good shows of gas were also found in the Trenton in the wells near Hazel Green, Madison County.

KNOX HORIZON.

The Cambro-Ordovician Knox dolomite has occasionally given small shows of gas; and since dolomitization with its attendant shrinkage should indicate increase in pore space and in capacity as a reservoir, this formation has been tested several times in the hope of its proving productive. But, as the Knox lies unconformably below the Trenton and where exposed shows a high degree of deformation, its possibilities for petroleum are so slight as to be unworthy of serious consideration.

The possibilities of the Knox as a gas producer are good throughout the north and northwestern portions of the State. A small show of gas was found in the Knox in the Huntsville well, Madison County, and in the Frankfort well, Franklin County, and in the Haleyville well, in Winston County, the Knox produced some 40,000 cu. ft. of gas per day.

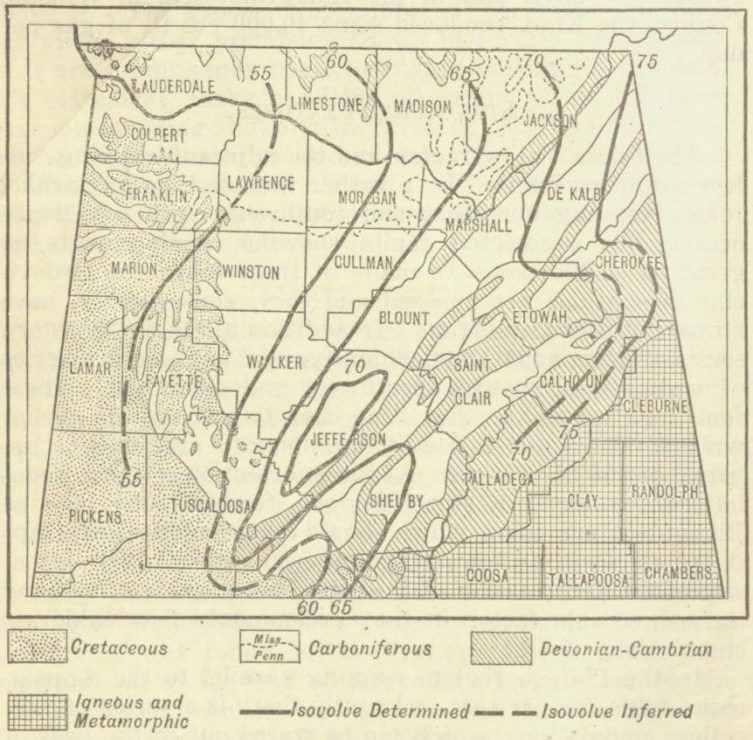
STRUCTURAL FEATURES.

The Coosa Valley region and the adjacent outlying valleys are characterized by a rather intense type of parallel folds, trending northeast and southwest, with which are occasionally associated faults showing displacements as great as 10,000 feet. In many of these folds, the Ordovician formations are exposed and they, consequently, have no possibilities as oil traps. In addition to the northeastern series of prominent Appalachian-type folds, there is a series of undulations running northwest and southeast. These folds, or "waves" as they have been termed by the earlier writers, are sometimes quite pronounced and show a reversal of 100 ft. or more. At the intersection of these undulations quaquaversal structures are formed, such as the Blount Springs dome, which should make excellent oil traps if the oil horizons themselves are not exposed. The intensity of the deformation of this area, however, is considered an unfavorable factor in the development of valuable accumulations of oil.

In the Plateau region, running parallel to the Appalachian folds farther east and south, there is a series of subsidiary undulations, which can be traced out in the beds of the Coal Measures. In this area are likewise developed the series of northwest-southeast waves, and at the intersection

of these two series more or less perfectly developed domes are occasionally established. Unfortunately, the most favorable portion of the Pennsylvanian area, the western part, is rather extensively covered by the Lafayette gravels and the Cretaceous series, or by a mantle of residual soil, which makes the locating of favorable structures a difficult task; and after evidence of folding has been found, it is often impossible to map the structures in detail.

In the Tennessee Valley region, especially in the area underlain by the Mountain Limestone group (Morgan, Lawrence, Franklin, and Colbert Counties), the two series of undulations can be readily detected; and owing to the character of the surface rock the structure can be accurately mapped. Since the most favorable oil horizon, the Trenton,



GEOLOGICAL MAP OF NORTHERN ALABAMA, SHOWING CARBON RATIOS.

FIG. 15. Geological map of Northern Alabama showing carbon ratios. (Courtesy *Mining and Metallurgy*.)

occurs in this area at a depth of 1,000 to 2,000 ft., the area is considered very favorable for future prospecting.

Significance of Carbon Ratios of Coals of Area.

A recent paper by Fuller,* discussing the relation of the carbon ratios of the Pennsylvanian coals to the oil fields of northern Texas, has interested the writer in collecting and plotting the fixed carbon percentages of the Pennsylvanian coals of northern Alabama. In certain localities, a sufficient number of analyses were obtainable to locate the isovolves† definitely; in other areas, their location was largely inferred. On the accompanying map, the direct relationship between the fixed carbon and the amount of deformation is very apparent. Even such outlying folds as the Sequatchie anticline have their definite effect upon the percentage of fixed carbon in the coal mined along their flanks. The degree of metamorphism attending this deformation has been shown by David White‡ to be definitely related to the distribution and composition of the oils found in the formations affected. When metamorphism has reached such an extent that the fixed carbon in the coals, considered on a basis of pure coal, has reached a percentage of 70, it is very improbable that oil pools of commercial importance will be found. In the case of northern Alabama, the writer believes that all areas where the fixed carbon runs as high as 65 per cent. may be considered as unfavorable territory and unworthy of extensive tests, until at least the areas of lower percentages have been tested and oil found in paying quantities. An examination of the accompanying map shows that the 65-percent. isovolve becomes definitely fixed near Huntsville and swings southward and westward across Madison, Marshall, Cullman, and Blount Counties, and along the northwestern line of Jefferson County, thence across Tuscaloosa County, swinging around the southwestern end

* Myron L. Fuller: Relation of Oil to Carbon Ratios of Pennsylvanian Coals in North Texas. Econ. Geol., Vol. 14, pp. 536-542 (June, 1919).

† The term "isovolve" has been adopted by Fuller, in the paper first cited, to signify a line drawn through points of equal carbon ratio.

‡ David White: Some Relations in Origin Between Coal and Petroleum. *Jnl.* Wash. Acad. Sci., Vol. 6, pp. 189-212 (March 16, 1915).

David White: Late Theories Regarding the Origin of Oil. *Bull.* Geol. Soc. Amer., Vol. 28, pp. 727-734 (Sept., 1917).

of Jones' Valley anticline into Shelby County, thence southward again following the crystalline area. Farther east, the 70-per cent. and the 75-per cent. isovolves swing around the areas of more intense folding and attendant metamorphism. To the north and west of the 65-per cent. isovolve, the 60-per cent. isovolve is less definitely located; and owing to the scarcity of analyses of the coals of Marion and Franklin Counties, the location of the 55-per cent. isovolve is in part inferred.

Favorable Areas.

If we are to consider the relation between metamorphism and oil distribution and composition as established, we are led to the conclusion that all the Coosa Valley region and much of the Plateau Region is unfavorable territory, and would expect in this area only small accumulations of light oil. West and north of the 65-per cent. isovolve there should be better chances for larger accumulations, provided we have the other necessary requirements of favorable section and structure.

The Pennsylvanian series shows a fairly favorable section, several good sands, and good structure where it can be worked out. Most of the area underlain by the Coal Measures lie within the 65-per cent. isovolve; to the west, the Coal Measures are covered by the Lafayette and Cretaceous formations. In the Fayette district, which is near the 55-per cent. isovolve, only gas was found in paying quantities, which would indicate that the degree of metamorphism was still too great for accumulation of oil. Considering, therefore, all evidence obtained so far, the Pennsylvanian area is not considered favorable territory except toward the western line of the State. In this area a hole drilled to 2,500 or 3,000 ft. would test the Hartselle sandstone as well as the Pennsylvanian horizons.

To the north, the Pennsylvanian formations break off forming a pronounced scarp facing the north. Passing down over this scarp, one comes upon a fairly level plain underlain by the lower members of the Bangor limestone. The upper, more massive members of this limestone form the base of the scarp. Farther north, beyond the plain underlain by the lower Bangor limestone, another scarp is formed by the Hartselle sandstone, locally known as Little Mountain. Between these two scarps there might be found

favorable structure, where the Hartselle is sufficiently covered to prove productive; this area is rather limited, however, for which reason practically no tests have been made of the Mississippian horizons.

By drilling at any point north of the Pennsylvanian scarp, the upper Trenton horizons (Goyer horizon) would be encountered not more than 2,000 ft. (609 m.) in depth. This would give a large territory comprising most of Morgan, Lawrence, Colbert, and parts of Franklin and Lauderdale Counties, in which the type of structures commonly considered as oil traps are fairly abundant, the degree of metamorphism is comparatively low, and the section is decidedly favorable. It is this area, and especially in Franklin, Colbert, and Lawrence Counties, that the writer would suggest that future tests be made. Numerous anticlinal folds can be found in the Hartselle sandstones and in places definite closure can be worked out.

Past and Present Development.

The past and present development of oil and gas prospecting and the results obtained together with the logs of the more important tests are discussed in detail in the county descriptions that follow. The following is a chronological list of the outstanding tests that have been made in northern Alabama. The logs and descriptions of these wells can be found under the respective counties:

1865. Watson wells, southeastern Lawrence County; good shows in two wells; Trenton horizon.

1890. Newmarket well, Madison County; strong petroleum odor, but no sand; Trenton horizon.

1891. Goyer wells, southeastern Lawrence County; one estimated at 25 bbl. a day; Trenton horizon.

1893. Allen wells, Florence, Lauderdale County; one dry, the other showed small quantities of very light oil and some gas, well spoiled by shooting; Trenton horizon.

1904-5. Huntsville and Hazel Green, Madison County; gas shows at both localities; Trenton horizon.

1909. Fayette wells, Fayette County; one estimated at 4,000,000 cu. ft. of gas; Pennsylvanian horizon.

1910-11. Shannon wells, Jasper, Walker County; 50,000 cu. ft. of gas, oil show; Pennsylvanian horizon.

1911-12. Woodward Iron Co., Russellville, Franklin County; small gas show in Knox dolomite (?).

1912. Bryan, Jefferson County; oil and gas show; Pennsylvanian horizon.

1916. Cordova, Walker County; good show, black residual oil; Pennsylvanian horizon.

1917-18. Atwood well, Franklin County; gas indications; Pennsylvanian horizon.

1917-18. Aldrich Dome wells, 6 mi. southeast of Birmingham, Jefferson County; gas shows; Pennsylvanian horizon.

1918. Guin well, Lamar County; oil shows in two sands; Pennsylvanian horizon.

1919. Hobson well, Frankfort, Franklin County; drilling at 1765 ft. (Dec.), small oil and gas shows; Trenton horizon.

The evidence of the above tests strongly supports the carbon ratio hypothesis, as all localities near the 65-per cent. isovolve showed gas and only small shows of oil. The heavy oil found at Cordova (26.5° Be). is an exception, but this was undoubtedly a pocket of residual oil, the lighter volatile constituents of which had been driven off.

Future Prospecting.

The area the writer considers most favorable for future testing is the northwestern portion of the State, where the Trenton limestone would be the producing horizon. Even this area is not without its disadvantages. The degree of metamorphism increases not only near areas of deformation but in depth in any locality as is shown by the progressive increase of fixed carbon in the successively older coal beds in passing downward in a normal sedimentary series.* Therefore the degree of incipient metamorphism of the Ordovician and Cambrian limestones, once covered to great depths by the younger Paleozoic formations, may be much greater than is indicated by the Pennsylvanian coal, in which case commercial accumulations of oil would be improbable. For this reason the Knox dolomite is not regarded by the writer as a potential oil producer, even though its possibilities for gas production may be good.

Upon the whole, however, considering the structure, the lithologic character of the section, and the evidence of the carbon ratios of the overlying Pennsylvanian coals, the area is undoubtedly worthy of further tests, provided they be well located on carefully determined structure.

In addition to the northwestern corner of the State, the Coal Measures, where exposed in Winston, Marion, and Fayette Counties, should be well worth testing, especially where drilling is continued to sufficient depths to test the Hartselle and the Trenton horizons.

* This principle now regarded as established is known as the law of Hilt (see Carl Hilt, Ann. Assn. d'Ingenieur de Liege, p. 287, 1873). It is subject to certain exceptions, but under normal conditions is universally applicable.

COUNTY DESCRIPTIONS

BIBB COUNTY.

GEOLOGY AND STRUCTURE.

Bibb County is located at the southern end of the highly folded and somewhat metamorphosed Coosa Valley region. Throughout most of the southern and western part of the county the folded Paleozoic formations are covered by the gravels and clays of the Tuscaloosa formation (Cretaceous), which effectually conceal the structure of these older sediments. Farther north the Coal Measures are uncovered and there they occur in a broken syncline. The high percentage of fixed carbon in the coal of this area indicates that there is very little possibility of oil production. However, small gas pools might be found in the sands of the Coal Measures where the structure is favorable. Between Centerville and the Coal Measures to the north the older Paleozoics outcrop and even the possible oil and gas horizons are exposed, so that in this area there is no chance for production.

DEVELOPMENT.

Some diamond drill holes have been sunk in prospecting for coal and iron, but no oil or gas showings of consequence have been reported.

BLOUNT COUNTY.

GEOLOGY.

Blount County lies in the plateau or upland region separating the valleys of the Coosa and the Tennessee. The Coal Measures form the surface throughout the county except for two anticlinal valleys, which traverse the county from northeast to southwest. In Brown's valley, the northernmost of the two, the Paleozoic series as far down as the Silurian (Niagara) limestone is exposed in the valley floor. In Murphree's valley to the south the series as far down as the Knox dolomite is exposed. (Sections 11-15, Plate II.)

STRUCTURE.

The dominant structural features of the county are the two prominent Appalachian-type folds. The Brown's valley anticline, a southward continuation of the Sequatchee anticline, pitches gently to the southwest, with successively younger formations swinging around its southern end, so that the fold is covered by the Coal Measures just beyond the southern line of the county. The axis of the Murphree's Valley anticline is practically horizontal, except at its northern end where it pitches slightly to the northeast. Throughout its entire length the Knox dolomite is exposed, so that it offers no possibilities for either oil or gas.

In addition to these two very prominent folds there are other minor undulations that roughly parallel them. Moreover there is a separate and distinct series of folds developed almost perpendicular to the northeast-southwest series. These undulations or waves are not pronounced, but they can be readily detected by careful examination. At the intersections of these two systems favorable structures are sometimes formed. The Blount's Spring dome (Fig. 16) is a structural high point or node on the major Se-

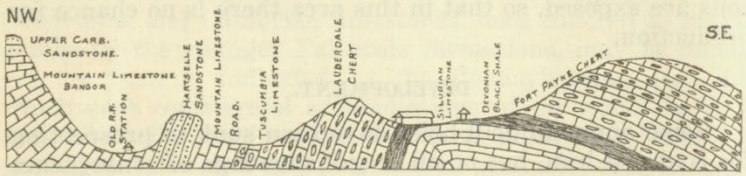


FIG. 16. Cross-section of the Brown's Valley anticline at Blount Springs showing the asymmetrical character of the Appalachian folds and the normal development of the middle and upper members of the Paleozoic series of Northern Alabama.

quatchee anticline that probably lies at the intersection of this large fold and one of the less pronounced undulations developed at right angles to it. On Blount Mountain near the line between Blount and St. Clair Counties there is another anticline beginning at Greasy Cove and thence running southwest towards Sec. 3, T. 14 N., R. 1 E., some ten or more miles. This anticline is not breached throughout its development on Blount Mountain, so that structural high points or nodes developed along its axis would be favorable points for gas accumulation.

The folding so prevalent throughout the county is accompanied by faulting, which in some places involves extensive movements. The northern flank of the Brown's Valley anticline is faulted at Blount's Springs, and on the northern side of Murphree's Valley near Altoona the Coosa Shales are faulted against the Clinton, representing a movement of over a thousand feet.

DEVELOPMENT.

No tests made solely for oil or gas have been reported from Blount County though numerous holes have been drilled in prospecting for coal and iron. Some oil seeps have been reported, and in several places the rocks are locally saturated with petroleum.

CALHOUN COUNTY.

GEOLOGY AND STRUCTURE.

Calhoun County is underlain by highly folded and faulted, and in places highly metamorphosed sediments ranging in age from the pre-Cambrian to the Lower Carboniferous. Throughout the county the possible oil and gas horizons are repeatedly exposed and on the whole so greatly metamorphosed that there would be no chance for oil or gas accumulation in commercial quantities.

CHEROKEE COUNTY.

GEOLOGY AND STRUCTURE.

Cherokee County like Calhoun lies in the Coosa Valley proper, and only along its northwestern line do we find any of the upper Paleozoic formations still uneroded. Throughout the rest of the county the possible oil and gas-bearing formations are repeatedly exposed as well as highly folded and faulted. The coal from the northern part of the county, moreover, shows an exceptionally high percentage of fixed carbon (75 per cent.), so that the county as a whole can virtually be classed as impossible territory.

COLBERT COUNTY.

GEOLOGY.

Surface gravels and clays cover extensive portions of the southern and western part of this county. These gravels may be either Lafayette formation or Tuscaloosa formation, but in either case they effectually conceal the structure of the underlying Sub-carboniferous strata. Throughout the southern part of the county, in the stream beds, the Hartselle sandstone outcrops. The northern limit of the Hartselle is marked by a pronounced scarp, that continues eastward throughout the next two counties and is known as Little Mountain. North of Little Mountain the Tuscumbia limestone forms the broad flat floor of the Tennessee Valley, and this limestone has weathered leaving a heavy mantle of red soil, so that exposures throughout this area are comparatively scarce. (Section 14, Plate II.)

STRUCTURE.

In that portion of the county where the Hartselle sandstone is exposed the structure can be readily determined, and it is evident that folding is rather widespread. The prevalent types of structure are the northwest-southeast waves and occasionally cross-folds are found. One test is now being made across the south line of the county on one of these undulations. Throughout the area underlain by the Tuscumbia limestone the structure cannot be accurately determined, so development in this area must go on blindfolded.

DEVELOPMENT.

No tests for oil or gas have been reported from Colbert County. Numerous seeps and some tar springs have been found in the Hartselle sandstone region, and in some places this sandstone is impregnated with petroleum over extensive areas.

CULLMAN COUNTY.

GEOLOGY.

Cullman County lies almost wholly in the Plateau Region, the resistant beds of the Coal Measures forming a rather elevated, partially dissected plateau, that is locally

termed Sand Mountain (to be differentiated from Raccoon Mountain also called Sand Mountain). Near the northern line of the county the Coal Measures plateau breaks off sharply, forming a pronounced scarp at the foot of which the strata of the Mountain limestone group reach the surface. (Section 14, Plate II.)

Analyses of the coals from Cullman County show that the fixed carbon runs rather high, about 64 per cent. Although this is not too high for oil accumulation it indicates that gas would be more likely to occur.

STRUCTURE.

The well-exposed series of the Coal Measures lends itself readily to the determination of the structure of the area. Folding is apparently widespread and the two distinct systems of folding that have already been mentioned are both evident; those folds aligned northwest-southeast, and those northeast-southwest.

DEVELOPMENT.

No wells drilled for oil have been reported, but several water wells were drilled in the vicinity of Cullman, one reaching a depth of 1,320 feet. No oil or gas were reported from these wells.

DEKALB COUNTY.

GEOLOGY AND STRUCTURE.

Topographically and structurally DeKalb County is readily divided into three parts: Wills' Valley, a sharp anticlinal valley of the Appalachian type, and the two broad gentle synclinal mountains lying to either side; Sand Mountain to the northwest and Lookout Mountain to the southeast. In Wills' Valley the Knox dolomite is exposed and it, therefore, offers no chance for oil or gas production. The two adjacent mountains underlain by the Coal Measures are synclinal in general structure and the coal from these areas, moreover, shows a very high percentage of fixed carbon (75 per cent. or more), so that it is exceedingly unlikely that oil will be found in the county in paying quantities. (Sections 1-4, Plate II.)

ETOWAH COUNTY.

GEOLOGY AND STRUCTURE.

This county, lying mostly in the Coosa Valley, is underlain throughout most of its southern and eastern portion by the Coosa shales, which are stratigraphically lower than any known oil horizon, and so can be regarded as impossible territory. In the northern part of the county the Coal Measures occur in the southwest end of Lookout Mountain and in the northern end of Blount Mountain, but in these areas the degree of metamorphism as shown by the high fixed carbon percentages of the coal is so great as to preclude the possibility of oil in commercial quantities. (Sections 5-9, Plate II.)

DEVELOPMENT.

A well was drilled near Gadsden in 1919. The results of this test have not been ascertained, but considering the highly folded and faulted character of the Paleozoic series in this locality, only negative results could be expected.

FAYETTE COUNTY.

GEOLOGY.

The sandstones and shales of the Coal Measures underlie the entire extent of Fayette County, but they are exposed in only limited areas, for throughout most of the county the Tuscaloosa sands and clays form the surface, and it is only along the streams that the Cretaceous cover has been cut through and the Coal Measures brought to light. The Tuscaloosa series occasionally shows a thickness of several hundred feet, but is usually less than a hundred feet. The Coal Measures in the southern part of the county aggregate over three thousand feet in thickness, while in the north where the upper beds have been removed by erosion the Tuscaloosa may be separated from the Lower Carboniferous by only 1,000 feet of these sediments.

STRUCTURE.

The widespread cover of younger and unconformable formations makes it impossible to determine the structure of the Coal Measures in many areas by the study of the sur-

face structure. In other places the Coal Measures are sufficiently exposed to enable the geologist to get the general structure even if he cannot work out the details. In these localities it can be seen that the strata of the Coal Measures show frequent warping and occasional faulting. It is undoubtedly true that structures favorable for oil and gas accumulation frequently occur in the county, but unfortunately they can only rarely be recognized.

The structure of the territory lying east of Fayette Courthouse, including the Fayette gas field has been studied carefully and a structural map has been published by the Geological Survey of Alabama.*

In those portions of the area included in this map where the Coal Measures are exposed they are seen to be frequently slightly folded. Several hypothetical domes were worked out, which have not yet been tested. It is evident, however, that folding is widespread in this area, even though it can rarely be recognized.

No coal analyses were obtained from Fayette County, but at Corona just over the eastern line of the county, the coals showed an average of 56 per cent. of fixed carbon, which should be sufficiently low to permit the accumulation of large pools of a good grade of oil. But on the contrary in the Fayette field some twenty miles west of this point only gas was found. In the opinion of the writer, however, this simply indicates that the original geological conditions were not favorable for oil formation, and not that subsequent deformation has made it impossible for oil once formed to be preserved and accumulated in commercial quantities.

DEVELOPMENT.

Development in Fayette County has been centered around the gas field, near the station of Gas Wells just southeast of Fayette, in the valley of the Sipsey river. In 1909 a diamond drill hole was put down at this point in search for coal. This hole reached a depth of 425 feet, encountering two sandstones with slight shows of oil. Encouraged by these indications a company was formed and two deep tests were made adjacent to the diamond drill hole. On December 20, 1909, one of these wells reached a gas-

* Reconnoissance Report on the Fayette Gas Field, Alabama, by M. J. Munn, Geological Survey of Alabama, Bull. 10 (1911).

bearing sandstone at about 1,400 feet in depth and began producing at an estimated rate of 1,600,000 cubic feet of gas a day at a closed pressure of 630 pounds to the square inch. The original Eureka Company was merged with the Providence Oil and Gas Company, this first producer being known as the Providence No. 1. The other test located about 100 feet on the other side of the diamond drill hole was continued to the depth of 1,685 feet, but only small shows of oil and gas were encountered. After the discovery well several other tests were made in rapid succession. The Providence No. 8, completed about March 1, 1910, came in at an estimated rate of 4,500,000 cubic feet of gas a day from the same sand, proving to be the best producer in the field. The No. 6 came in April 15 of the same year, producing from two to three million cubic feet a day. The Providence No. 3, drilled about a half mile from the railroad station at Fayette, was continued to 2,200 feet with only a small show of gas. Providence No. 9 came in around a million cubic feet, but later turned to salt water. Since then a half dozen wells have been drilled within a few thousand feet of the proven field, and a score or more in other parts of the same general territory but all without success as far as commercial production is concerned. The Providence No. 18 was drilled about 4 miles due east of Fayette on the Lewis land to the depth of 1,986 feet with only small shows. The Providence No. 19 on the Newton farm to the north of the gas field drilled into the lower conglomerate (Millstone Grit) getting only a strong flow of fresh water. The log of this well is as follows:

Log of Providence Well No. 19 on Newton Farm.

Thickness of strata Feet		*Total depth* Feet
45	Alluvium	45
65	Sand	110
130	Slate	240
3	Coal	243
112	Slate	355
2	Coal	357
58	Slate	415
45	Sand (showing of gas at 460)	460
40	Slate	500
30	Lime	530
40	Slate	570
20	Lime	590
85	Shale	675
30	Black lime	705
80	Sand	785
	At 765 small showing of salt water which soon exhausted.	
10	Black slate	795
95	Bluish lime	890
25	Slate	915
170	Sandy lime and slate	1085
35	Black slate	1120
25	Sand	1145
20	Sandy shale	1165
75	Sand (hole full of salt water at 1190 feet)	1240
100	Black lime	1340
45	Black and shelly	1385
215	Sand	1600
	Traces of oil at 1385 and small showing of gas. Hole filled with salt water at 1395 feet.	
75	Black lime	1675
95	Lime, sand and shells	1770
145	Sandy lime and slate	1915
	Show of gas at 1915.	
50	Sand	1965
25	Slate	1990
112	Sand	2102
	Strong flow of fresh water at 2065, overflowing hole at 2102.	

The Providence No. 25, one of the last wells to be drilled by this company was located quite near the discovery well. It also continued into the Millstone Grit and likewise got a flow of water.

Log of Well No. 25 on Sprinkle Farm, Providence Company.

Drilling commenced September 13, 1912; abandoned December 20, 1912.

Thickness of strata Feet		*Total depth* Feet
20	Soil	20
	Pieces of coal showing on spud.	
260	Sand	280
	Showing of oil at 210.	
90	Slate	370
75	Sand	445
	Showing of oil at 380.	
5	Slate	450
120	Black limey slate	570
40	Lime shells	610
90	Sandy shale	700
60	Shale and shells	760
40	Shale	800
45	Sand	845
35	Black lime	880
60	Shale	940
20	Sand	960
	Showing of oil first screw in this sand.	
80	Shale	1040
95	White sand	1135
155	Shale and shells	1290
25	Sand	1315
155	Black slate	1470
8	Black sand	1478
	This sand had slight petroleum odor.	
6	Black lime	1484
34	Lime, shells and slate	1518
105	Shale	1623
80	Sand	1703
	Salt water at 1640.	
25	Black sand	1728
77	Slate	1805
20	Shells	1825
20	Slate	1845
40	Sand	1885
5	Sandy shale	1890
50	Sandy lime	1940
10	Black sand	1950
40	Slate	1990
108	Sand (some water at 2000)	2098
77	Sandy shale	2175
15	Sand (water increasing)	2190

None of the wells of the Fayette district has been continued to sufficient depth to test the Hartselle sandstone. At Bankston, about 10 miles east of Fayette, the Freeman well of the Alabama Central Oil and Gas Company, after getting a good show of gas and small shows of oil in the Fayette sand, was continued downward with the intention of making a test of the Hartselle. One misfortune followed

another, however, and finally the tools were lost just before the top of the Hartselle was reached and the well abandoned. As this is the deepest well in Fayette County and of much significance in showing the nature of the entire thickness of the Coal Measures in this locality its log is given in full herewith:

Log of Freeman Well, Bankston, Alabama.

Elevation 466 feet.

		Thickness	*Depth*
Tuscaloosa	Cretaceous sand	15	15
	Black slate	95	110
	Broken lime	75	185
	Black slate	85	270
	Coal	5	275
	Slate and shale	205	480
	Coal	3	483
	Fire clay	10	493
	Dark sand	40	533
	Slate	90	623
	Coal	5	628
	Fire clay	10	638
	Dark sand	35	673
	Broken lime	140	813
	Black slate	85	898
	Lime, shale	25	923
	Sand, show of oil 10 feet from top	55	978
	Black shale	150	1128
	Sand, show of oil 5 feet from top	85	1213
	Broken lime	30	1243
	Black slate	225	1468
	Sand, gas and show of oil 10 feet from top	90	1558
	Slate and shale	15	1573
	Black slate	138	1711
	Sand, good show of gas 90 feet from top	225	1936
	Black slate	40	1970
	Sand, show of gas in bottom	50	2020
	Black slate	20	2040
	Sand	10	2050
	Black shale	35	2085
	Sandstone, large amount of salt water 145 feet from top, and 4-foot coal seam at 2250 feet	265	2350
Millstone Grit	Limey shale	10	2360
	Sandstone	184	2544
	Salt water at 2475 feet and 2530 feet.		
	Limestone, rotten	160	2704
Mountain Limestone (Bangor)	Red Rock (limestone?)	50	2754
	Limestone to bottom of the hole	178	2932
	Supposed to be on top of the Hartselle sandstone when the tools were lost and the hole abandoned.		

COAL MEASURES

In the southern part of the county in Sipsey swamp near Newtonville two wildcat wells were drilled by the Five Rivers Oil Company, but no shows of importance were encountered.

During the present winter (1919-20) further geological examination of the southeastern part of Fayette County and the northern part of Tuscaloosa County has been carried on by one of the larger oil companies (Sinclair Oil and Refining Company) as a result of which two holes will be drilled in the vicinity of Berry.

FRANKLIN COUNTY.

GEOLOGY.

The covering of Lafayette and Tuscaloosa gravels, sands, and clays extends over the entire county, especially in the upland interstream areas. Underlying these sediments unconformably the Carboniferous formations are exposed in the valleys (Fig. 18). In the southern part of the county, extending as far north as Isbell and Bel Green the Coal Measures are found underlying the Tuscaloosa. No definite scarp separates this belt from the Sub-carboniferous formations as is the case farther east, but the country is very

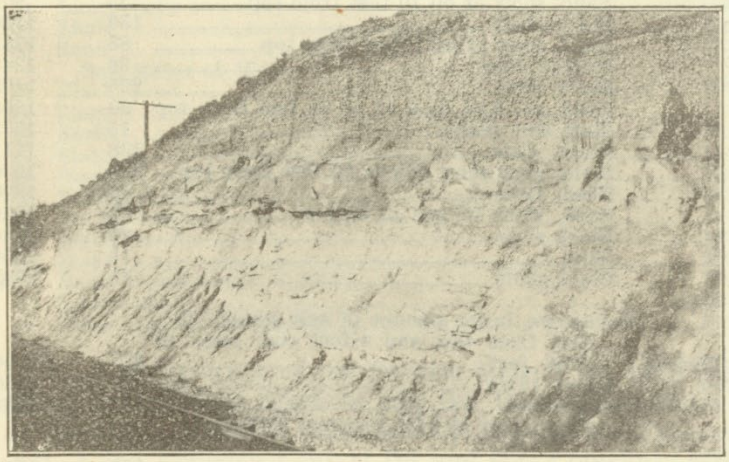


FIG. 18. A cut on the Illinois Central R. R., 4 miles east of Hackleburg, Marion County, showing the Lafayette and Tuscaloosa gravels lying unconformably upon the eroded surface of the Coal Measures. (Photo by R. M. Harper.)

rugged; the streams developing gorges in the lower sandstones of the Coal Measures. From Bel Green northward the Mountain limestone group is exposed in the valleys, and along Cedar Creek and in the northeastern corner of the county the Hartselle sandstone phase appears, breaking off as a north-facing scarp (Little Mountain) in Colbert County.

STRUCTURE.

The fact that throughout the greater part of Franklin County the Carboniferous formations are overlain and concealed by younger formations prevents the accurate determination of the structure of these underlying formations. Enough can be seen, however, to make it evident that these sediments have been gently folded in many places in the county. In the area where the Bangor limestone and Hartselle sandstone outcrop these folds are much more evident and are seen to be generally aligned northwest-southeast. One of the most pronounced of these undulations or waves is located just west of Frankfort on the northern line of the county. At a high point on the axis of this fold a well is now being drilled.

No coal samples have been obtained from Franklin County, but as indicated by the isovolve map, (Fig. 15) the degree of metamorphism is low and the possibility of oil accumulation is as good as in any other portion of northern Alabama. In the southern part of the county the Hartselle might prove a pay sand and to the north the Tuscumbia and Trenton should be reached at less than 1,500 feet.

DEVELOPMENT.

In 1911 the Woodward Oil and Gas Company sank a hole six miles southeast of Russellville.

Woodward Oil and Gas Company, Well No. 1.

SUMMARY RECORD.

Formation	*Character of Material*	*Thickness*	*Depth*
Bangor	Limestone, oolitic, white	288	288
	Shale, calcareous, gray	42	330
	Limestone, white	40	370
	Shale, dark gray	62	432
Hartselle	Sandstone, fine, calcareous	164	596
	Shale, calcareous, gray	134	730
	Limestone, compact, gray	20	750
	Sandstone, coarse, calcareous	10	760
Tuscumbia	Limestone, cherty in part	147	907
Lauderdale	Chert and limestone	308	1215
Devonian	Shale, calcareous, brownish black	25	1240
Clinton	Shale, calcareous, red and green	140	1380
	Limestone, greenish white	20	1400
Trenton	Shale, calcareous, black	215	1615
	Limestone, brown to white	150	1765
	Sandstone, fine, calcareous	50	1815
	Limestone, white to gray and brown	475	2290
Knox	Dolomite, light gray, granular, oily	270	2560

WATER.

First water (fresh) at 265 feet.
Second water (brackish) at 475 feet.
Third water (salt) at 2295 feet.
The salt water continued to the bottom of the hole, with a notable increase at 2330 feet.

GAS.

A small but persistent flow of gas was encountered at 1645 feet, in the Trenton limestone.

OIL.

Traces of oil and the odor of oil were noted from 1750 to 1830 feet, in the Trenton sandstone and limestone; and the odor of oil was very marked in the Knox dolomite from 2295 feet to the bottom of the hole. No oil or gas was noted in the Hartselle sandstone.

In 1917 a test was begun on the Moss farm near Atwood with cable tools and completed to the depth of 2,609 feet with a diamond drill. This well was not located upon any favorable structure, and considering the promising shows that were encountered it should recommend rather than condemn the territory.

Log of Test Hole Sunk On J. L. Moss Farm, Atwood, Alabama, Section 26, Township 8, Range 14, Franklin County.

(Cable Tools to 1,820 Feet.)

	Formation	Ft. Thick	Depth
PENNSYLVANIAN	Soil	10	10
	Gumbo (black fire clay)	20	30
	Sandstone shell, hard	3	33
	Gumbo, black and soft	32	65
	Slatey sandstone	10	75
	Gumbo, black	13	88
	Sandstone, light	4	92
	Blue fire clay	3	95
	Green sandstone	25	120
	Dark shale	12	132
MISSISSIPPIAN	Limestone	4	136
	Red rock, soft	10	146
	Limestone	27	173
	Sandy limestone	13	186
	Red rock, soft	5	191
	Sandy limestone	88	279
	Slate, soft	2	281
	Red rock, soft	10	291
	Limestone, light, pure	61	352
	Slate	2	354
	Limestone	16	370
	Slate	2	372
	Sandy limestone	15	387
MISSISSIPPIAN Bangor Limestone	Limestone	77	464
	Limestone, very hard	50	514
	Sandy limestone, hard	52	566
	Slate, soft (some salt water)	18	584
	Sandstone	7	591
	Limy slate	53	644
	Limestone	2	646
	Soft slate	3	649
	Limestone	11	660
	Soft slate	1	661
	Limestone	9	670
	Sandy limestone	20	690
	Limy slate	80	770
MISSISSIPPIAN Hartselle	Sandstone	38	808
	Asphalt 775-808—Limy sandstone	37	845
	Slate	1	846
	Limy sandstone with trace of asphalt	26	872
	Sandy limestone	49	921
	Sandstone (shows lime)	10	931
	Sandy limestone	29	960
	Pure slate	58	1018
	Limestone shell	2	1020
	Limy slate	62	1082
	Limestone	25	1107
	Limy sandstone	13	1120

	Formation	Ft. Thick	Depth
Tuscumbia	Limy slate	4	1124
	Sandy limestone (show of gas)	4	1128
	Limestone	12	1140
	Sandstone (show of oil)	3	1143
	Limestone, very hard	109	1252
	Limy sandstone	16	1268
	Dark limestone (show of oil)	4	1272
	Limy sandstone	16	1288
Lauderdale	Sandy limestone, very hard	80	1368
	Coarse gray limestone	9	1377
	Dark shale, some lime	24	1401
	Sandy lime, very hard	42	1443
	Limestone	75	1518
Devonian	Light, limy sandstone	12	1530
	Limestone, very hard	70	1600
SILURIAN Clinton	Slaty lime, soft	8	1608
	Slaty lime, hard streaks	131	1739
	Slate, soft, limy	23	1762
	Hard limestone	11	1773
	Red rock, limy	38	1812
	Red rock, blood red changing to lighter at bottom of hole	8	1820

DIAMOND DRILL CONTINUATION.

(In the main by W. J. Douglass.)

SILURIAN Clinton	1820–1825	Very white crystalline limestone. (Would make a very pretty marble.)
	1825–1841	Green and black shales.
35 ft.	1841–1855	Dary gray sandy limestone.
	1855–1876	Dark gray sandy limestone.
	1876–1896	Dark limy shale. Contains sand and is almost entirely lacking in slaty structure.
	1896–1913	Shaly, sandy limestone. Pyritiferous or chalcopyritiferous in last 2 feet.
	1913–1927	Shaly, sandy limestone. Pyritiferous or chalcopyritiferous in last 2 feet.
	1927–1937	Shaly formation. Conglomeratic in appearance.
	1937–1957	Alternate shale and limestone.
	1957–1977	Alternate shale and limestone.
	1977–2016	Shale. Pyritiferous in places. Last 4 feet crystalline limestone with (2012) indication of oil.
21 ft.	2016–2026	Limestone crystalline.
	2026–2037	Limestone, dense.
	2037–2052	Limestone, denser, with thin slate beds.
85 ft.	2052–2073	Crystalline limestone, massive in places.
	2073–2106	Continuation of above.
	2106–2127	Continuation of above.
	2127–2137	Continuation of above, with thin, irregular beds of shale.
	2137–2163	Continuation of above.

ORDOVICIAN Trenton	73 ft.	2163–2240	Continuation of above. Limestone varies from white to brown and crystalline to semi-crystalline.
	31 ft.	2240–2271	Dark gray limestone, massive.
	13 ft.	2271–2284	Dark gray limestone, massive, hard.
	26 ft.	2284–2298	Semi-crystalline limestone.
		2298–2310	Dense, hard limestone. Dark gray.
		2310–2318	Dense, hard limestone, with occasional thin beds of shale.
		2318–2331	Dense, hard limestone with occasional thin beds of shale.
	20 ft.	2331–2351	Hard, white, dense limestone. Cuttings show a thin black formation.
	116 ft.	2351-2370	Dense limestone, white (greenish blue).
		2370–2446	Dense limestone, white (greenish blue).
		2446–2467	Dense limestone, white (greenish blue).
		2467–2588	Dolomitic formation. Fine grained.
		2588–2609	White dolomitic formation. Strong ooze of oil for over 5 feet.

NOTE.—By S. A. Hobson: At 2423 grew cherty with occasional vertical splits in core. At 2446 grew seemingly dolomitic, core rather uniform in structure, finely crystalline, of lighter color.

Either Knox or Lower Trenton	Buff dolomite containing oil struck at 2588. Gas, probably 2 first feet. Buff dolomite 2588-2609. Only went 21 feet in this great sand. A heavy shot would probably pay in this 21 feet without going further even.

Oil sand a dolomitic limestone, beautiful yellow, as the core came out; leached rapidly to white from evaporation. Oil extra fine quality, very clear except for yellow tinge. Gas: rock pressure probably 1,000 lbs. though open flow small, from tightness of the sand.

Encouraged by the shows that were struck in the Atwood well another hole was started by S. A. Hobson on a well-defined structure near Frankfort. The test started in on the Hartselle sandstone with the Knox dolomite as the final objective, but it was hoped that production would be found at higher horizons. The results of this test have not been encouraging. Small shows of oil were found in both the Tuscumbia and the Trenton, but the top of the Knox has now been reached and though gas may be found the chance for oil in paying quantities is remote. The following is the log of the Frankfort well down to 1,765 feet. At the present writing (March, 1920) drilling has been continued in the Knox to about 2,000 feet with negative results.

Log of Frankfort Well, Drilled by United Oil Company in N.E. Corner of N.W. ¼, S. 7, T. 6, R. 12.

Begun about middle of September, 1918.

		Ft. Thick	Depth
HARTSELLE SANDSTONE	First stroke of drill in Hartselle sandstone (the thick massive upper sandstone of the Hartselle formation). Massive, fine-grained silicious sandstone, with occasional somewhat limy streaks	150	150
	(Note—Small quantity fresh water 20-50 feet. from 75-90 feet very rich saturation of heavy, dead oil, none of which would flow into hole.)		
	Limy shale	85	235
	Massive, slightly sandy limestone	15	250
	(Note—Set 8-inch casing at 253.)		
	Shales with occasional ledges of limestone	25	275
	Limy sandstone, black, with *rich saturation of dead, black oil*	6	281
	Irregular alterations of gummy shales and more or less sandy limestones	69	350
	Massive sandy limestone	25	375
Lower Bangor	Irregular alterations of vari-colored amorphous cavy shales (in places highly fossiliferous) and limy sandstone ledges; latter saturated with dead oil	22	397
	(Note—Caves compelled resetting of 8-in. at about 407.)		
	Gray limestone	3	400
Tuscumbia Limestone	Lighter colored limestone	62	462
	(Note—Sprightly gas at 400, stronger at 413, small additional oozes at sporadic intervals all along to 465—about enough, in aggregate, when burned in boiler over night to show 20 pounds of steam next morning.)		
	Massive gray to white limestone with occasional cherty inclusions (about)	113	575
	Whitish, slightly sandy limestone, showing, between 575 and 580 feet, about 1/3 of a boiler per hour of slightly salt water	15	590
Lauderdale Chert	Gray to white limestones, intercalated with layers or stringers of chert, occasionally showing inclusions of black, dead oil residue, viscous and sticky as chewing gum	45	635
	Sandy limestone with many cherty intersperse-ments	53	688
	Very dark limestone with many cherty interspersements and shaly intercalations	64	752
	(Note—Strong flow of salt water at bottom of last item; unable to get cuttings of last few screws; 6¼-inch casing set at 760-8 feet.)		
	Hard, cherty limestone	18	770
Devonian	Black shale	14	784

		Ft. Thick	Depth
SILURIAN Niagara	Slightly sandy white limestone; so white slush looked like stream of clabber	65	849
	(Note—A little salt water at 790.) Greenish to grayish shales	68	917
SILURIAN Clinton	Sandy limestone with reddish, highly ferruginous argillaceous inclusions	10	927
	Same, growing more ferruginous	18	945
	Hematitic limestone, with apparently little or no silica	30	975
	Same, with slightly less iron	23	998
Trenton Limestone	Gray shale; limy; with some hard ledges	132	1130
	Hard sandy limestone with slight gas odor	20	1150
	Shaly limestone with sporadic 1-2 ft. hard ledges	85	1235
	Limestone making pinkish-brown slush with slight gas odor	175	1410
	White limestone	53	1463
	Darker limestone	87	1550
	Hard cherty ledge	3	1553
	Limestone	7	1560
	Dark colored limestone, slightly softer, with strongly oil-smelling slush	25	1585
	White limestone	30	1615
	Hard ledge	8	1623
	Irregular alterations of variable thicknesses (2-10 feet) hard and soft limestone	47	1670
	Hard cherty limestone	12	1682
	Softer limestone	12	1694
	Very hard limestone, dark to light colored	71	1765
Knox dolomite	Light colored limestone (probably dolomitic) with slight gas right at the top.		

JACKSON COUNTY.

GEOLOGY.

Jackson County is readily divided into the southeastern area of Coal Measures, a portion of Sand or Raccoon Mountain; the central Sequatchee Valley, occupied by the Tennessee, along which all the Paleozoic formations down to and including the Knox are exposed; and the northwest half of the county, where the Coal Measures are again exposed in isolated plateaus, except along the stream courses where they have been removed by erosion, and the limestones of the Sub-carboniferous exposed.

STRUCTURE.

The principal structural feature of Jackson County is the Sequatchee anticline, an asymmetrical fold of the Ap-

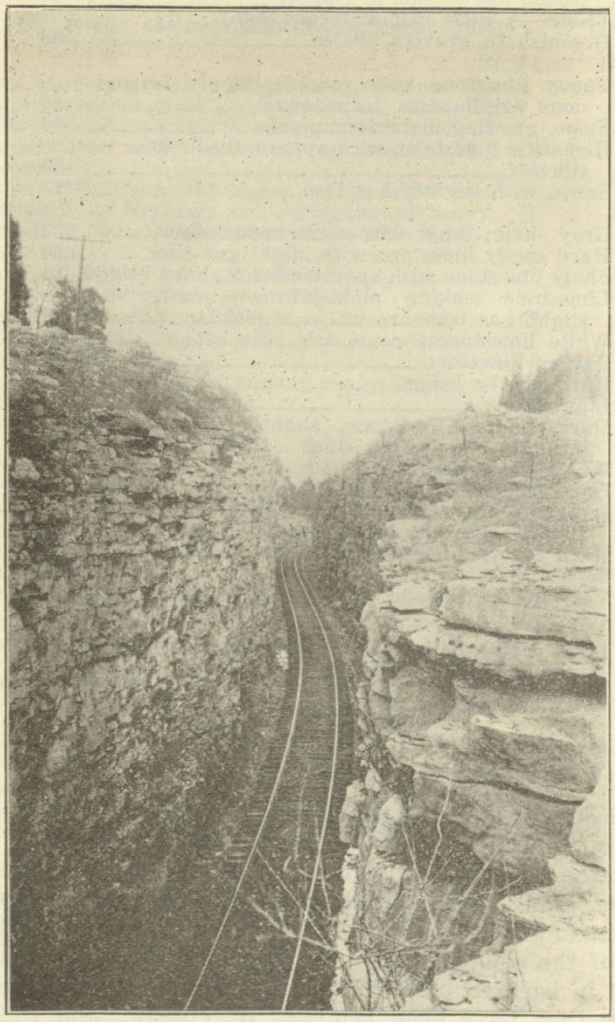


FIG. 17. A cut in the Bangor limestone near Lim Rock, Jackson County. In adjacent counties this limestone occasionally shows extensive oil saturation. (Photo by R. M. Harper.)

palachian type showing a steeply inclined northwest flank, which is locally faulted. Along the axis of this fold the Knox dolomite is exposed throughout the entire length of the valley, so the anticline is of no value as an oil or gas trap. To the southeast on Sand Mountain the Coal Measures occur in a broad gentle syncline. Minor anticlines or domes in this area might be worth testing for gas, but oil could not be expected. In the Carboniferous area northwest of the Sequatchee Valley similar structures can be located, but it must be remembered that this area lies in the general synclinal region between the main Appalachian Uplift and the Cincinnati-Nashville Arch. Moreover the degree of metamorphism is rather high so that a test in this region could hardly be expected to produce anything more than gas from the Trenton or Knox (Sections 1-3, Plate II.)

DEVELOPMENT.

In 1913 a well was drilled near Bridgeport, but encountering the Knox dolomite at a comparatively shallow depth, the well was abandoned at about 500 feet.

During the same year a well was drilled in the vicinity of a gas seep about two miles north and a little east of Stevenson, at a point near the base of the Bangor limestone. A show of gas was encountered at about 900 feet in the Clinton. Drilling was continued to 1,700 feet in depth, or about the base of the Trenton, with no other shows of importance.

JEFFERSON COUNTY.

GEOLOGY.

In Jefferson County the entire Paleozoic series with the exception of the Weisner quartzite is represented, showing an aggregate maximum thickness of 12,000 feet. The county can be divided into four distinct divisions: First, the Cahaba Valley, a portion of which extends into the southeastern end of the county. This is an anticlinal valley of the Appalachian type and along its floor are exposed the Ordovician and Cambrian strata, including the Coosa shales. Secondly, the Cahaba coal field proper, an upland plateau area of approximately 100 square miles in extent in this county, in which the Coal Measures show a maximum thickness of over 5,000 feet. Thirdly, the Jones or Birmingham

Valley district, traversing the county from northeast to southwest, in which, like the Cahaba Valley, the series as far down as the Knox dolomite is exposed, and fourthly the Warrior coal field covering over half of the county, an area of some 600 square miles, in which the Coal Measures are developed in maximum thickness of over 4,000 feet. This last area is by far the most important of the county from the point of view of oil or gas production.

STRUCTURE.

Jefferson County lies wholly in the region of the folded Appalachians and its general structure can be summarized as three sharp parallel Appalachian folds including two much gentler synclinal areas. These anticlines are all of the Appalachian type showing steep northwestern limbs, more frequently faulted than otherwise, and the normal northeast alignment. The southernmost of the three, the Cahaba Valley, is separated from the Cahaba coal field on the north by a thrust fault showing much over three (possibly ten) thousand feet of stratigraphical displacement, the Montevallo shales being brought into juxtaposition with the beds of the Coal Measures. The Cahaba coal field is generally synclinal, being abruptly terminated to the south of this fault. The Birmingham anticline is complex, showing several minor wrinkles whose axes are marked by thrust faults of considerable displacement. This is especially the case in its northeast extension in the northeast corner of the county, where the valley broadens out to eight or ten miles and four or five distinct anticlinal axes can be recognized in crossing it. (Sections 16-23, Plate II.)

The Warrior coal field, like the Cahaba, is bounded on the south by a fault. The general structure of the Warrior field is synclinal, but in the northern part of the county the basin is broken by the southward continuation of the Sequatchee or Brown's Valley anticline, which in this area is a gentle fold with a maximum inclination on the northern limb of 30 degrees. The higher beds of the Coal Measures cover this fold as it pitches rapidly to the southwest. In the syncline between this anticline and the Birmingham Valley the Coal Measures are developed in great thickness and it is in this area that many of the largest coal mines of the State are located.

As the Cahaba Valley and the Birmingham Valley anticlines can be eliminated there remain the Cahaba and Warrior basins and the Brown's Valley anticline where oil or gas accumulation could be possible. An examination of the map showing the fixed carbon ratios of northern Alabama (Fig. 15) shows that throughout the whole county the percentage of fixed carbon is so high that oil accumulation in large quantities would be extremely improbable. For this reason the writer does not believe that any part of Jefferson County is favorable oil territory, but the possibilities

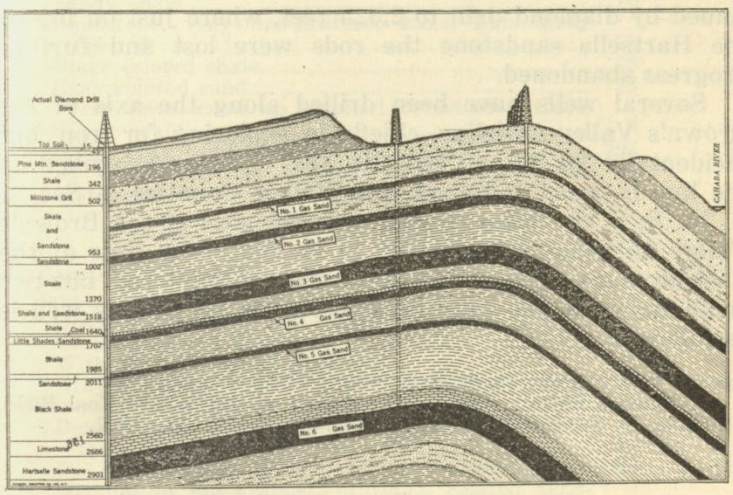


FIG. 19. A generalized section of the Aldrich Dome, Jefferson County, based upon the core of the diamond drill hole in its vicinity. The sands represented are possible gas horizons but only the first has yet proved productive. (Courtesy of T. H. Aldrich, Jr.)

for gas in commercial quantities are good, and it is not at all unlikely that valuable gas pools will be developed in the county.

DEVELOPMENT.

The possible gas territory is therefore the Cahaba and Warrior coal fields and the Brown's Valley anticline. South of Birmingham on the northern outskirts of the Cahaba basin several anticlines and domes have been located in the Coal Measures; some of these have been mapped in detail by

the U. S. Geological Survey,* and it is evident that they are true domes and should make excellent gas traps. One of them, Dolly Ridge or Aldrich Dome, has already proved productive in a small way. This dome extends from Sec. 27, T. 18, R. 2 W. to Sec. 12, T. 19, R. 3 W., and has been tested by five shallow wells ranging in depth from 165 to 225 feet. Three of these have proved productive, their capacity being roughly estimated at 75,000 to 1000,000 cubic feet a day (Fig. 19). A deep test to the Hartselle sandstone was started by the Dixie Gas Company, but at 2,300 feet the tools were lost and the hole abandoned. Later it was continued by diamond drill to 2,523 feet, where just on top of the Hartselle sandstone the rods were lost and further progress abandoned.

Several wells have been drilled along the axis of the Brown's Valley anticline, chiefly in exploring for iron, but incidentally for oil and gas. In 1911 a well was drilled on the line between Jefferson and Walker Counties in Sec. 1, T. 15, R. 5 W., being located near the axis of the Brown's Valley anticline and starting in on the lower beds of the Coal Measures. No shows of oil were encountered, but two small shows of gas were reported. The log of this well is as follows:

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* Charles Butts: The Northern Part of the Cahaba Coal Field, Alabama, U. S. Geol. Survey, Bulletin 316, pp. 76-115. 1907.

Final Record of Test Well No. 2, Located in the Center of Section 1, Township 15, South of Range 5 West. Elevation 484 Feet.

Started February 12, 1911. Completed May 5, 1911.
Record by John A. Udden.

	Thickness	*Depth*
Recent:		
Surface soil	4	4
Pennsylvanian—Coal Measures:		
Brown sandstone, weathered	15	19
Gray sandstone with occasional shales	58	77
Sandy shale	10	87
Sandstone, very fine-grained, hard, light gray colored	78	165
Black colored shale	95	260
Gray colored sand	28	288
Fresh water came up within 110 feet of surface.		
Sandy shale	8	296
Light gray sandstone	392	688
At about 650 feet another water horizon was struck.		
Mississippian-Sub-carboniferous:		
Bangor formation—		
Grayish limestones and shales	67	755
Grayish colored limestone	402	1157
With show of gas at 1148 feet.		
Grayish colored limestone with some black shale	20	1177
Hartselle formation—		
Dark colored, medium-grained sandstone in which there was water	18	1195
Dark gray shale	26	1221
Medium to fine-grained, brownish colored sandstone, slightly calcareous	9	1230
Tuscumbia formation—		
Dark shaly limestone containing varying amounts of siliceous matter	179	1409
Dark gray shaly limestone, show of gas, flow of salt water	4	1413
Grayish colored limestone in which there was some siliceous matter	67	1480

Farther southwest along the axis of this anticline a deeper well was drilled by the same company (Tennessee Coal, Iron & Railroad Company) to the depth of 3,130 feet. This well is located in Sec. 27, T. 15, R. 5 W., and penetrated almost through the Trenton limestone. Some very encouraging shows were found.

Log of Well No. 1, Northeast of Bryan, Alabama, Section 27, Township 15 South, Range 5 West.

		DEPTH	
		Top	*Bottom*
COAL MEASURES Millstone Grit	Surface soil	0	6
	Sandstone	6	70
	Shale with interbedded sandstones	70	220
	Sandstone	220	465
	Shale, dark	465	500
	Sandstone, with thin shaly layers	500	855
	Gas show at 595 feet.		
	Shale, dark, carbonaceous	855	870
	Sandstone, coarse-grained, conglomeratic, with some shaly streaks	870	960
Bangor	Limestone, dense, massive, bluish color. Occasional shaly layers	960	1500
Hartselle	Sandstone, brown, coarse-grained	1500	1630
	Gas show at top of sand.		
	Shale, dark calcareous	1630	1700
Tuscumbia	Limestone, dark cherty	1700	1955
Lauderdale	Chert, very hard, pinkish	1955	1970
Devonian	Shale, black	1970	1975
	Limestone	1975	1995
	Limestone, sandy	1995	2025
	Limestone, ferruginous	2025	2055
	Sandstone, brown	2055	2065
	Limestone	2065	2075
Silurian Clinton	Sandstone, brown, grading into ferruginous sandstones of the Clinton	2075	2345
	Shale, reddish	2345	2365
	Sandstone, brown	2365	2400
Ordovician Trenton	Limestone, massive, gray to dark blue in color, with occasional shaly and sandy horizons	2400	3130
	Small show of oil in fine-grained limestone, good for one-half barrel a week, at about 3100 feet. The well was shot June 20, 1911. At first no oil showed but later about the same amount as before the shot.		

Still farther southwest along this axis the Pratt Consolidated Coal Company is making two deep tests; the first of these, located near Flat Creek in Sec. 19, T. 16, R. 5 W., has been completed to the depth of 3,087 feet, getting numerous shows of oil and gas and a large amount of gas at 1,231 feet. A very careful log has been made of this well, which is given below:

Record of Test Well No. 1, at Flat Creek, Alabama.

Location: Northeast quarter of northwest quarter, Section 19, Township 16 South of Range 5 West, at Flat Creek, Alabama.
Started: May 28, 1916.
Completed: October 27, 1917.
Elevation: 412 feet.
Churn Drill hole to 2262 feet. Diamond Drill hole, 1⅛-foot core, below.
Drilled for Pratt Consolidated Coal Company.
Record of Diamond drilling by C. S. Blair.

		Thickness		*Depth*	
		Ft.	In.	Ft.	In.
COAL MEASURES	Surface	8	.....	8	.....
	Coal: *Jagger (?) Seam*	1	.....	9	.....
	Fireclay and soft slate	8	.....	17	.....
	Sandstone gray	21	.....	38	.....
	Slate, dark	32	.....	70	.....
	Hard shell lime	6	.....	76	.....
	Slate	40	.....	116	.....
	Sandy slate, hard	10	.....	135	.....
	Slate and sandy shell	35	.....	170	.....
	Sandstone, gray and hard	20	.....	190	.....
	Slate, dark and colored	13	.....	203	.....
	Coal: *Black Creek Seam*	1	.....	204	.....
	Sandstone with oily smell	36	.....	240	.....
	Slate with hard streaks, light colored	120	.....	360	.....
	Very hard sandstone with hard streaky slate	155	.....	515	.....
	Sandstone, dark gray, very hard, show of gas at 548	68	.....	583	.....
	Slate and lime shells	40	.....	623	.....
	Sandy shell, very hard	17	.....	640	.....
	Slate, soft; some lime	65	.....	705	.....
	Sandy shell, smell of oil	4	.....	709	.....
	Lime, slate, hard	28	.....	737	.....
	Sandstone, very hard, gray	38	.....	775	.....
	Sandy slate, soft	10	.....	785	.....
	Hard gray sandstone, show of gas at 794	154	.....	939	.....
	Slate	86	.....	1025	.....
Millstone Grit	Hard sandstone	211	.....	1236	.....
	(Note—Some water at 1200 feet, with show oil coating tools at 1215 feet. Large amount water at 1222 feet with large amount of gas with enough pressure to come through well full of water at 1231 feet.)				
	White open sandstone (gas with show of oil in top 4 inches)	74	.....	1310	.....
	Slate	10	.....	1320	.....
	No record	80	.....	.....	.....
	Hard sandstone at base of the Coal Measures	150	.....	1550	.....

		Thickness Ft.	In.	Depth Ft.	In.
MISSISSIPPIAN	Shale	34	.....	1584	.....
	Limestone (Bangor)	376	.....	1960	.....
	No record	45	.....	2005	.....
	Hartselle sandstone, fine-grained, brown sandstone	120	.....	2125	.....
	No record	137	.....	2262	.....
	Dark colored limestone with black shale partings; mostly fine-grained (Tuscumbia)	309	.....	2571	.....
	Limestone and chert, chert seams to 8 feet thick	10	.....	2581	.....
	Limestone, coarse crystalline, white to pink colored with green shale and ferruginous partings (Lauderdale chert)	126	.....	2707	.....
DEVONIAN	Hard brown sandy shale, green in places	6	.....	2713	.....
	Pinkish, coarse, crystalline limestone	6	.....	2719	.....
	Greenish shale, limestone seams	18	.....	2737	.....
	Brown hard limy shale and shaly limestone	30	.....	2767	.....
	Fine-grained brown shaly sandstone	8	.....	2775	.....
	Green shale	15	.....	2790	.....
	Fine-grained brown shaly sandstone	8	.....	2798	.....
CLINTON	Ferruginous sandstone, lean ore	0	6	2798	6
	Fine-grained brown shaly sandstone, green shale partings	30	6	2829	.....
	Green shale, 2 feet lean ore at top	4	6	2833	6
	Lean ore	0	3	2833	9
	Green shale	1	3	2835	.....
	Gray sandstone, fine-grained	1	5	2836	5
	Lean ore	6	8	2843	1
	Sandstone, fine-grained, lime streaks	10	11	2854	.....
	Sandstone, fine-grained, shale partings	16	.....	2870	.....
	Green shale	6	3	2876	3
	Lean ore, mottled with white lime fossils	0	3	2876	6
	Green sandy shale	2	0	2878	6
	Lean sandy ore	0	6	2879	.....
	Shale	1	3	2880	3
	Lean ore	0	3	2880	6
	Sandstone, fine-grained	16	6	2897	.....
	Mottled brown shale interbedded with coarse crystalline limestone in about equal amounts	25	.....	2922	.....
	Iron ore	2	8	2924	8
	Coarse pink crystalline limestone with ore interbedded shaly in places, ore about 50% rock	20	4	2945	.....
	Fine-grained shaly sandstone green shale interbedded	50	4	2995	4
	Ore, good fine-grained (one piece analyzed ran 43.20 in iron)	7	2	3002	6
	Green shale	0	1	3002	7
	Ore	0	1	3002	8
	Shale	0	4	3003	.....
TRENTON	White limestone, shale partings	1	8	3004	8
	Black shale	1	.....	3005	8
	Shaly limestone, black shale interbedded, shale decreasing in depth	130	.....	3135	.....

The second well now drilling near Praco at 3,200 feet is being drilled with a diamond drill and the core has been carefully preserved. It started in at a point about a hundred feet stratigraphically higher than the well at Flat Creek. In other respects the two logs correspond closely. Mr. S. A. Hobson has carefully examined and described the core to the depth of 3,150 feet, and the following log is based upon his observations:

Praco Diamond Drill Hole, Near N.E. Corner Section 36, Township 16 South, Range 6 West.

Starting a few feet below the level of the Mary Lee Coal Seam.

		Thickness	*Depth*
COAL MEASURES	Shales and arenaceous shales	120	120
	Sandstone, tight, fine-grained	30	150
	Shales and sandy shales	60	210
	Sandstone, medium to coarse-grained with a few shaly layers	35	245
Fayette Sand, Upper & Lower Conglomerates	Coal seam of undetermined thickness, probably Black Creek seam.		
	Shaly sandstone and alternating shales and sandstones	360	605
	Sandstone, fine-grained micaceous	20	625
	Shales and sandstones alternating	525	1150
	Sandstone, massive with occasional thin shaly layers. A few small pebbles near bottom	535	1685
	Conglomerate, massive throughout without a break	30	1715
	Oil saturation in places from 1680-1715 feet.		
	Shales, with occasional thin conglomerates	100	1815
	Sandy shale or lime	20	1835
	Shales, thin-bedded, fine-grained	64	1909
MOUNTAIN MILLSTONES Bangor	Limestone, dense, bluish, locally arenaceous or argillaceous	296	2205
	Shale, calcareous, with thin limestone and sandstone horizons	20	.....
Hartselle	Sandstone, fine-grained, with occasional shaly horizons	107	2313
	Oil saturation at irregular intervals.		
	Shales growing calcareous towards base	161	2474
	Marly limestone	11	2485
Tuscumbia	Limestone, massive, slightly shaly towards top	95	2580
	Oil saturation at frequent intervals.		
	Gas sand 2498-2505, very porous, composed of shell fragments.		

		Thickness	Depth
Lauderdale	Chert and cherty limestone	165	2745
Devonian	Shales, dark, calcareous	87	2832
SILURIAN Niagara	Limestone, massive	14	
	Limestone, massive, highly ferruginous	20	
Clinton	Shales, ferruginous	20	
	Shales, varicolored, calcareous layers	109	3000
	Shales, ferruginous	5	3005
	Sandstone, shaly, slightly ferruginous in places	145	3150
	Bottom of hole, March 1, 1920		3350

While the wells that have just been described have been located approximately upon the axis of the Brown's Valley anticline, still it has been noted that this fold pitches rapidly to the southwest along this portion of the axis. Considering the favorable gas shows that have appeared in these tests it should certainly be worth while to make a careful survey of the entire length of the fold in Jefferson County to determine if there is any point where the pitch is reversed and a node or dome developed along the crest. Such a point should have very good possibilities as a gas trap. The writer has made only a cursory examination of the region, but from what he has seen he believes that such structures do exist and can be located by careful examination.

LAMAR COUNTY.

GEOLOGY.

The entire surface of Lamar County is covered by the gravels, sands, and clays of the Tuscaloosa and Lafayette formations, except a few square miles along the larger stream courses of the northeastern part of the county, where the underlying Coal Measures are exposed.

STRUCTURE.

The Tuscaloosa formation lies unconformably upon the Coal Measures and shows a general dip to the southwest. Owing to the unconsolidated or partially unconsolidated na-

ture of these sediments exposures are rare and the local structure is difficult to determine. As the two series are separated by an unconformity favorable structures that might occur in the concealed Coal Measures would probably have no reflection at the surface in the Tuscaloosa series, or structure developed in the Tuscaloosa would not continue unchanged down into the Coal Measures. Therefore the geologist is greatly handicapped and production, if developed at all, must be developed by the wildcatter.

A recent analysis of coal from T. 12, R. 14 W., Lamar County shows that the fixed carbon is comparatively low, 58 per cent., which would indicate that the accumulation of high grade oil would not be impossible in the Coal Measures and the underlying horizons.

DEVELOPMENT.

One wildcat test has been made in the county which got such good shows that the promoters of the enterprise were encouraged to continue their efforts in Marion County. This well is known as the Guin well, drilled by Frederick Morck in 1918, just west of the town of Guin in the N.E. ¼ of S.E. ¼ of Sec. 25, T. 12, R. 14 W.

Log of Guin Well.

		Thickness	*Depth*
Tuscaloosa	Surface casing	.....	138
	Gumbo and running sand	30	168
	Shale and red sand alternating	37	205
	Gumbo and sand	235	440
Fayette sand	White sand	135	575
	Slate	134	709
Upper Conglomerate	Light gray sand	86	775
	Dark sand	330	1105
	Sands alternating in color and porosity	6	1111
	Black sand	7	1118
	Dark gray sand	100	1218
	Black shale	27	1245
	Dark sand	35	1280
Lower Conglomerate or Millstone Grit	Gray sand (fine quality)	20	1300
	Black shale	50	1350
	Black shale continued	25	1375
	Dark sand	75	1450
	Gray slate	5	1455
	Gray slate continued	55	1510
	Red Sand	55	1565
MOUNTAIN LIMESTONE Hartselle Group	Upper Bangor: Light colored slate	45	1610
	Upper Bangor: Slate and lime alternating	64	1674
	Oil sand with oil	8	1682
	Hard dark lime	9	1691
	Second sand rich in oil	7	1698
	Hard lime shale	4	1702
	Close sugar sand richly saturated with oil	8	1710
	Shale, limestone and shells	34	1744
	Dark oil sand showing oil	6	1750
	Shale, limestone, etc.	40	1790
	Dark limestone	27	1817
	Dark hard limestone	68	1885
	Dark shale	15	1900
	Dark hard lime	25	1925
	Dark shale, soft	75	2000

The oil from this well coming from the 1,682-foot sand is very heavy and black (19° Baume), apparently a residual oil indicating that the well was not located on a structure that would have caused the accumulation of the entire oil content of the sand, but rather at a point where he lighter constituents could readily migrate off, leaving only the heavier constituents as a residual saturation.

LAUDERDALE COUNTY.

GEOLOGY.

The Tuscumbia limestone occurs in Lauderdale County as an irregular strip following the Tennessee River. North of this area the Lauderdale chert forms the surface throughout the entire county, with the exception of several small and irregular patches of Silurian and Trenton limestone. The strata of this formation are highly siliceous and have weathered forming slightly elevated plateaus and areas of rolling topography descending by sharp bluffs to the stream courses. The light siliceous soil of this area, underlain by the more or less cavernous chert, is rather infertile being generally covered with a growth of pine and oak, and is locally termed the Barrens.

STRUCTURE.

Careful mapping of the structure of the Lauderdale chert reveals the fact that it is warped into slight undulations generally aligned northwest-southeast. Where definite closure can be determined such structures should be worth testing for oil in the Trenton or gas in the Trenton or Knox. So far, however, no test has been made upon favorable structure.

Lauderdale County is situated on the top of the Cincinnati-Nashville Arch, and is also removed from the area of Appalachian folding, so the deformation is not such as would prevent the preservation of the oil, and the general structure is favorable for its accumulation. Lauderdale County, therefore, is a promising territory for future development. (Section 14, Plate II.)

DEVELOPMENT.

In 1893 the late Thurston H. Allen drilled two wells in T. 1 S., R. 10 W. The first was located in the N.W. ¼ of the N.E. ¼ of Sec. 22, and was drilled to 2,760 feet, but did not strike anything but faint traces of oil and gas in the Trenton. The second well was drilled in the S.W. ¼, Sec. 33, T. 1 S., R. 10 W., on Keethly Creek, a tributary of Shoal Creek, at an elevation of 586 feet above sea level. This well probably started in the top of the Silurian (Niagara) limestone and was continued to a depth of 1,460 feet. The following is a summary of the log of the well:

	Top	*Bottom*
Surface soil	1	15
Limestone, gray	15	240
Sandstone, calcareous, at places heavily charged with petroleum	240	330
Blue shale, siliceous	330	440
Oil sand, very light white oil	440	444
Limestone, whitish-gray (Trenton)	444	447
Good gas show, 15 pounds pressure.		
Limestone, darker than that in which the oil and gas was found	447	870
Black shale, bituminous	870	905
Sandstone, reddish, limy	905	930
Limestone	930	1460

The bottom of the hole was probably in the upper portion of the Knox dolomite. The well was shot with 72 quarts of nitro-glycerine, which blew out the casing and demolished the derrick. The owner claimed that this well was good for four or five barrels, but after spoiling the hole by shooting, no other tests were made.

The Florence-Sheffield Oil and Gas Company is now drilling a well near Florence, having reached the depth of 800 feet. The same company is also drilling two wells just across the State line at Iron City, Tennessee. One has reached 500 feet in depth and some very encouraging shows have been encountered.

LAWRENCE COUNTY.

GEOLOGY.

The normal dip of the strata in Lawrence County is slightly west of south, so the successive members of the Carboniferous series cross the county in approximately east-west belts, the older formations outcropping to the north. The Coal Measures capping Sand Mountain form a belt about ten miles wide, occupying the southernmost part of the county. At the foot of Sand Mountain the upper portion of the Mountain limestone group (Bangor limestone) reaches the surface and gives rise to a comparatively level belt of limestone topography, extending several miles north of Moulton. Beyond this point the Hartselle phase of the Mountain limestone outcrops, forming a north-facing escarpment (Little Mountain), north of Little Mountain the lower limestones of the Mountain limestone group reach the surface in a narrow belt, and beyond this the Tuscumbia limestone forms the level plains extending to the Tennessee River.

STRUCTURE.

The geological structure of Lawrence County can, throughout the greater part of the county, be accurately determined by close examination. Exposures are scarce in the northern part of the county, in the area underlain by the Tuscumbia limestone, which is a valley-making formation, easily eroded, and covered with a thick mantle of residual soil. In the southern two-thirds of the county numerous folds trending northwest and southeast can be detected and occasionally others parallel to the Appalachian trend can be seen. In the southeastern part of the county along Caps Creek, a tributary of Clifty Creek, both of these sets of undulations can be recognized. Two tar springs occur in the synclinal trough between two of these undulations on the south bank of the creek in the S.W. ¼ of Sec. 26, T. 8, R. 6 W. The Watson wells described below were drilled near these two tar springs. About five miles southeast of Moulton in Sec. 12, T. 7, R. 7 W., the limestones are folded into waves trending northwest-southeast. Well-defined closure could probably be worked out in this area, but as yet no prospecting has been carried on.

Lawrence County lies well up on the Tennessee-Nashville Arch and is removed from the area of high metamorphism, so for both of these reasons it should be a promising territory for prospecting. Moreover, the Trenton horizon has produced oil in small quantities in the southeastern part of the county, and as this horizon should be reached at less than 1,500 feet in almost all parts of the county the cost of prospecting would not be prohibitive. On the whole the writer regards it as one of the favorable areas of the State for future prospecting. (Section 14, Plate II.)

DEVELOPMENT.

The first wells actually drilled for oil in Alabama were the Watson wells, drilled about 1865 by Jonathan Watson, in the vicinity of the oil springs in the southeastern corner of Lawrence County (S.W. ¼ of Sec. 26, T. 8, R. 6 W.). Several wells were drilled by Watson, and it was reported that good shows of oil were encountered in two of them. These wells were comparatively shallow (700-800 feet), probably reaching the top of the Trenton, where the oil shows were found.

In an adjacent township to the Watson wells there were six wells drilled by the Moulton Valley Oil Company, from 1890 to 1892, known as the Goyer wells. The first of these wells, the Goyer No. 1, is located in the northwest corner of the S.W. ¼, S.E. ¼, Sec. 29, T. 7, R. 6 W., and reached the depth of 2,120 feet. This well got an excellent show of light green oil (38.7° Baume) and was estimated at twenty-five barrels a day by Dr. McRae, the geologist in charge. A careful log was made of this well which is as follows:

*Log of Goyer Well No. 1.**

		Feet
36	Soil	10
35	Limestones; Bangor	290
34	Sandstones; *first gas*, in the upper part	35
33	Shales; a dark blue color	110
32	Limestone; of a pearly white, sulfuretted hydrogen gas was struck in this rock at 55 ft. below its top and salt water at 53 ft. from its top; the salt water on evaporation gave a good flavored salt	80
31	Limestone; of a light drab color	320
30	Limestone; impure, coming out as a coarse powder like corn-meal and hence called "corn-meal sand"	28
29	Shales; Devonian, black	32
28	Limestones; shaly	17
27	Limestones; blue	2
26	Shales; sandy and of a mottled (red and white) color	9
25	Limestone; it carries some little oil	422
24	A gritty calcareous sand, likely from an impure limestone	100
23	Limestone; blue	45
22	Limestone; coarse grained, the lower 5 ft. is an oil sand though it carries no oil	9
21	Limestone; coarse grained, impure and siliceous, a good oil sand. *Oil*	20
20	Limestone; blue	261
19	Limestone; white	32
18	Limestone; blue with greenish specks	6
17	Limestone; white or cream colored	6
16	Limestone; blue	63
15	Limestone; bluish with a slight reddish tinge	26
14	Limestone; white	27
13	Limestone; gray with a slight reddish tinge	4
12	Limestone; white	4
11	Limestone; gray with a few reddish specks	3
10	Limestone; of a light gray color	49
9	Limestone; white	5
8	Limestone; of light gray and reddish specks	2
7	Limestone; of a brownish gray color	5
6	Limestone; white	4
5	Limestone; of a grayish color with white and blue specks	7
4	Limestone; with large white specks that resemble pieces of fossils	4
3	A dark grayish powder with blue and white specks; it may be shale	5
2	Limestone; with white and light gray colors with reddish specks	22
1	Limestone; white	3

* From report on Valley Regions of Alabama, by Henry McCalley, Part I, p. 239, Geological Survey of Alabama (1896).

Of this above log, 35 is in the Bangor limestone, from 34 down into 31 is the Hartselle sandstone group; from 32 to 30 is the Tuscumbia limestone and Lauderdale chert; 29 is the Devonian; and the rest is Trenton.

The first gas was found in the top of the Hartselle sandstone at 302 feet in depth. It burned ten feet high out of the open end of the six-inch casing. The second gas was struck at 500 feet in the base of the Hartselle group. The production from these two gas sands together were estimated at 20,000 cubic feet per day. The first oil was only a trace, but at 1,530 feet the pay sand was struck and the oil rose to the height of two hundred feet in the well. Some eight barrels of oil were pumped out at this time, but soon afterwards the casing began to leak and salt water impaired the well. The well was then shot with 100 quarts of nitroglycerine, which partially demolished the casing and let in a flood of salt water, thereby ruining the well.

The Goyer well No. 2 was drilled about one and a half miles northwest of the Goyer No. 1 in the N.W. ¼ of Sec. 30, T. 7, R. 6 W. It was continued to 1,565 feet, but only got a show of oil. Quoting Dr. McRae, the geologist: "We completed our well No. 2 at 1,565 feet and found no oil. We found the oil sand all right but it yielded no oil." A good show of gas was struck at the top of the Hartselle sandstone at 220 feet.

These wells were not located with any special reference to geological structure, for at that time the relation between structure and oil accumulation was not fully appreciated. The writer has not visited the locality, but it is quite possible that the Goyer No. 1 was located at the crest of one of the northwest-southeast undulations so frequently developed in the county, and in this way the production could be explained. Since the Goyer tests were made no further prospecting for oil has been carried on in the county.

LIMESTONE COUNTY.

GEOLOGY.

In the southern part of Limestone County the Tuscumbia limestone forms the surface, dipping gently to the south. This formation extends from the Tennessee River almost as far north as Athens; from which point northward it has

been removed by erosion, and the underlying Lauderdale cherty limestone exposed. The Lauderdale chert forms the surface all the way to the State line, except along the principal stream courses, where erosion has laid bare the upper strata of the Trenton limestone.

STRUCTURE.

Limestone County lies well up on the eastern flank of the Cincinnati-Nashville Arch and consequently its regional structure is favorable. Throughout the entire county the Trenton horizon can be reached at less than 500 feet in depth. The Trenton is considered one of the most favorable horizons for oil and gas in the State, so the chances should be good for oil and gas, especially gas, accumulations throughout the county. However, there are two distinctly unfavorable conditions, first the Trenton is insufficiently covered in much of this area to become an important oil producer, and secondly, the determination of structure is rather difficult, especially in the area underlain by the Tuscumbia limestone. In the northern part of the county where the Lauderdale and Trenton limestones are exposed the outcrops are numerous and the structure can be accurately mapped. In this area there would be the possibility of gas in the Knox dolomite.

DEVELOPMENT.

No wells drilled for oil and gas have been reported from the county. Gas shows have been found in some of the deeper water wells that reached the top of the Trenton.

MADISON COUNTY.

GEOLOGY.

The Coal Measures in Madison County are confined to the high mountains in the eastern part of the county. The sandstones of the Coal Measures cap these mountains and make flat-topped mesas 1,500 to 1,800 feet above the sea, and from 800 to 1,300 feet above the adjacent valleys. Monte Sano, just east of Huntsville, a well known summer resort is on one of these plateaus nearly 1,000 feet above Huntsville. Throughout the rest of the county the Sub-

carboniferous limestones are exposed, except in the northern and northwestern portions where the Silurian limestone has been uncovered along the stream courses.

STRUCTURE.

The Lower Carboniferous limestones in the southern part of the county lie practically horizontal and favorable structure for oil accumulation is rare. In the northern part of the county folding is apparently more widespread and good structures are to be found. The major structure of the county is that of geosyncline, as it lies between the Appalachian Uplift and the Cincinnati Arch. The area, therefore, would be less favorable than that to the west. (Section 8, Plate II.)

The most favorable horizon for oil and gas production in the county is the Trenton limestone. The Knox is also a possible gas horizon. These two horizons should be reached throughout most of the county at less than 1,500 feet, and the Trenton at less than 500 feet. These formations would more likely produce gas than oil considering their age and their general proximity to the region of deformation. The possibilities for gas throughout the county are good, therefore, if the tests are made on well-defined structures.

DEVELOPMENT.

In 1905 a well was drilled at West Huntsville to the depth of 2,647 feet for T. W. Pratt. The log of this well has been lost, but as it started in on the Tuscumbia limestone it probably reached the base of the Trenton at about 1,200 or 1,400 feet and therefore penetrated about 1,200 feet of the Knox dolomite, which is over two thousand feet thick in this area. The well was not located with reference to structure, but got a large gas show. The Trenton limestone gave a strong odor of petroleum and good gas shows were encountered in the Knox.

About the same time six wells were drilled a mile northeast of Hazel Green, ranging in depth from 190 feet to 1,690 feet. Five of these wells were less than 600 feet in depth and got gas in the Trenton horizon. The two best producers, about 300 feet in depth, are still producing about 50,000 cubic feet a day. The gas from these two wells comes from near the top of the Trenton. The deep test penetrated well

into the Knox dolomite, but only a small flow of gas was obtained from this horizon. At New Market a well was drilled for oil some time ago and reached a depth of over 1,000 feet. No shows of consequence were reported.

A well is being drilled at Bell Factory, about ten miles northeast of Huntsville, with cable tools. This well has reached a depth of 300 feet.

MARION COUNTY.

GEOLOGY.

The Tuscaloosa formation covers by far the greater portion of the area of Marion County. All of the upland area is underlain by this series of sand and variegated clays, which lies unconformably above the Paleozoic, and it is only along the stream courses that the Coal Measures outcrop. In the southern part of the county the Coal Measures underlying the Tuscaloosa probably aggregate 1,000 feet in thickness, while on the northern line of the county only 500 feet or less of Coal Measures separate the Tuscaloosa from the Sub-carboniferous limestones. The topography is in many places rugged as the streams in cutting through the Tuscaloosa series developed rather precipitous gorges in the sandstones of the Coal Measures. At the head of these gorges there often occur massive overhanging ledges of sandstone forming what are known as "rock-houses." In some cases undercutting has gone on so far that part of the roof of the "house" back of the ledge has become loosened and fallen in leaving the outer edge as a natural bridge (Fig. 20).

STRUCTURE.

Since the Coal Measures are exposed in only limited areas it is a difficult task to determine the structure with any degree of accuracy. Certain horizons are found over extensive areas, however, and these can be used as keys to the local structure. The two conglomerates, the upper and the lower, can be readily recognized, though it is often impossible to determine whether a particular outcrop represents the top of either of the conglomerates or simply an eroded surface. It is more satisfactory to try to recognize the shale that separates the two conglomerates. This horizon is rather constant and it can be found throughout most

of the county. In the area south and east of Hamilton it can be recognized in the stream courses over an extensive area. It is found approximately at the water level in the principal streams from Sec. 18, T. 11, R. 13 W. to Sec. 25, T. 10, R. 14 W., indicating that instead of the normal dip to the southwest that should be expected there is in reality a terrace between the two points mentioned or possibly a reverse dip giving rise to a dome. In other parts of the county smaller structures have been reported, but it is difficult to determine accurately their size and trend. (Section 18, Plate II.)

The fixed carbon in the coal mined near Brilliant, as shown by analyses, is not high (56 per cent. fixed carbon), indicating that this county lies in a territory as favorable for oil accumulation as any part of northern Alabama. Moreover the Hartselle sandstone should be reached at about 800 feet in the central portion of the county, so that a test could be made even to the Trenton, without great expense. The formations do not cave readily and the drillers can count on making considerable hole a day with ordinary luck.

DEVELOPMENT.

Several diamond drill holes have been put down in the county, but none solely for oil. The deepest diamond drill hole is located about three miles northeast of Hamilton in Sec. 25, T. 9, R. 14 W. This hole was drilled in 1917 by the Gulf Producing Company, a Birmingham concern, to the depth of 2,200 feet in prospecting for iron. The drill pierced the Clinton, stopping in the Trenton limestone. Portions of the core smelled strongly of petroleum but no real shows were found. This, however, is not surprising, for the surface indicates that the well is located in a syncline.

Record of the Hamilton Well.

Drilled by the A-M Oil, Gas and Pipe Line Company in the northern part of Section 25, Township 10, Range 14 West, Marion County, Alabama, with diamond drill.

		Thickness	*Depth*
Upper Conglomerate	Soil	6	6
	Sandstone, coarse, with occasional shaly layers	75	81
	Alternating shales and sandstones	58	139
Lower Conglomerate	Sandstone, coarse-grained, conglomeratic occasional shaly layers	90	229
	Shales, dark, calcareous layers	151	380
	Coal 2 inches.		
	Shale, with limy and marly layers, and occasional thin sandstone	165	545
MOUNTAIN LIMESTONE Bangor	Limestone, dense gray crystalline, fossiliferous with interbedded thin shales and green marls. Three oil shows at 593, 670 and 703 feet, the latter a five-foot sandstone saturated with black oil	158	703
	Limestone, very porous, highly fossiliferous, dense crystalline gray, showing oil and gas at numerous horizons. Rather cherty towards the base	443	1146
Hartselle	Limy and sandy shales, dark	240	1386
	Sandstone, fine-grained, shaly	20	1406
	Sandstone above mentioned gave good show of oil.		
	Shales and interbedded sandstones	63	1469
	Sandstones and calcareous sandstones with good shows of oil and gas	24	1493
Tuscumbia Lauderdale	Limestones, dark crystalline, cherty in places, some shaly layers. Frequent oil shows. Grading imperceptibly into hard, dense, gray cherts. (Lauderdale chert)	227	1720
Devonian (?)	Shale, greenish black	18	1738
	Limestones, cherty, thin shale seams	124	1862
Silurian	Greenish marls and shales, with some layers of dense gray limestone, with occasional pinkish and purplish inclusions	249	2111
	Calcareous shales, greenish	12	2123
	Limestone, ferruginous, compact, greenish and pink	37	2160
Clinton	Iron ore, hematite, two feet	2	2162
	Limestone, fine-grained, ferruginous, pink	31	2193
Trenton (?)	Limestone, dense, dark gray, sandy	200	2393

Another test is just being commenced in Marion County a few miles southeast of Hamilton. This well, being drilled by Frederick Morck, is located in the S.W. ¼ of N.W. ¼ of Sec. 24, T. 11, R. 14 W., in the area mentioned above where there is good evidence of a terrace or dome. Drilling will be continued to the Tuscumbia and possibly to the Knox horizon. As this is the first well drilled in the northwestern part of the State, located on fair structure, which will test the Hartselle sandstone at a point where it is sufficiently covered to be productive, the writer awaits the results of the test with a good deal of interest.

MARSHALL COUNTY.

GEOLOGY.

The Carboniferous formations form the surface throughout this county, except in Brown's Valley, the southward continuation of the Sequatchee anticline, where the Paleozoic series down to the Knox dolomite is exposed. This valley divides the county into two almost equal areas underlain by Carboniferous formations; the southeastern half, a portion of Sand or Raccoon Mountain, and the northern half, which has been bisected by the Tennessee River on entering Brown's Valley, leaving Gunter's Mountain to the northeast and a similar patch of Coal Measures to the southwest.

STRUCTURE.

The main structural feature of this county is the sharp asymmetrical anticline that is now eroded down to a valley occupied by Brown's Creek and the Tennessee River. South of this anticline lies Sand Mountain, which is a broad synclinal expanse of Coal Measures. The axis of the Brown's Valley or Sequatchee fold pitches very gently to the southwest, but locally it may be horizontal or even show a reverse pitch so that high points or nodes may be developed along the axis. About eight miles southwest of Guntersville in Warrenton Valley there is a detached area of Knox dolomite, which no doubt represents such a node on the major axis, where local doming has brought up this lower formation. The Knox and overlying cherty limestones are very siliceous in this locality and numerous perfectly developed quartz crystals can be found in the soils of the valley floor. Some of these crystals are discolored and on crushing they

yield a strong odor of petroleum, and others show liquid inclusions, presumably petroleum. This was regarded as sufficient indication to warrant local parties in drilling for oil, and about 1890 a well was drilled to the depth of 1,000 feet. This well was named the *Wildcat Well,* a very appropriate term, considering that it started in at a horizon in the Knox, far below any known oil-producing horizon. (Sections 7-9, Plate II.)

Local anticlines and domes aligned either parallel or normal to the main Appalachian trend can be traced out in the Coal Measures both north and south of Brown's Valley. The high degree of metamorphism in this region would preclude the possibility of any large amount of oil, but gas pools might be developed by intelligent testing.

DEVELOPMENT.

No tests for oil or gas other than the Wildcat Well have been reported from Marshall County.

MORGAN COUNTY.

GEOLOGY.

Sand Mountain, capped by the lower sandstones of the Coal Measures, extends across the southeastern part of Morgan County. At the foot of this scarp the Bangor limestone outcrops, underlying a broad undulating plain, extending northward from five to fifteen miles. Throughout this area exposures are scarce and it is rather difficult to determine the structure. North of the Bangor outcrop the Hartselle sandstone is exposed, making another north-facing escarpment, which is called Little Mountain. The width of the Hartselle outcrop is variable, sometimes exceeding fifteen miles. North of Little Mountain are the level plains of the Tennessee Valley underlain by the Tuscumbia limestone.

STRUCTURE.

In the area underlain by the Hartselle sandstone, where the details of the structure can be determined it is evident that folding is very abundant. Most of the folds are of the northwest-southeast alignment and sometimes are fairly sharp, showing dips as great as 30 degrees. In the northern

and southern part of the county outside of the Hartselle belt the structure is more difficult to determine.

Morgan County is sufficiently removed from the Appalachian center of disturbance to make possible the accumulation of light oil, but it lies in the synclinal area between the Appalachian region and the Cincinnati-Nashville Arch, which must be considered an unfavorable factor.

Throughout the entire area in which the Hartselle sandstone outcrops oil seeps and asphalt and maltha showings are abundant. In many places the sandstone is permeated or even saturated with oil over considerable areas. These seeps indicate that the Hartselle should be a pay sand where occurring under sufficient cover and other favorable conditions, but it must be remembered that seeps in the Hartselle where it outcrops in Morgan County would mean nothing regarding the possibility of oil in the underlying Trenton horizon, which should be the objective for oil prospectors in this county.

DEVELOPMENT.

The numerous oil springs and seeps in the Hartselle sandstone have brought about the drilling of several wells in Morgan County for oil. In the eighties a well was drilled on the outcrop of the Hartselle sandstone about three miles to the southwest of Hartselle.* The depth of the well was not reported, but it was said that a good show of oil was encountered. Near Hartselle numerous oil seeps occur, and in 1887 a well was drilled at the site of Old Hartselle, about one mile north of the present depot on the old grade of the L. & N. R. R. This well was probably located at this point on account of an oil seep in a nearby lime-sink, but it happened to be also on the crest of a well-defined fold, trending N. 25° W. and showing a steeper west flank (30 degree dip). This anticline can be traced northward for some distance in the limestone outcrops that have been quarried to the north of the old town site.

* Misspelled "Hartsells" by P. O. Dept. for many years past.

*Log of the Old Hartselle Well.**

		Top	Bottom
(21)	Surface soil	0	17
(20)	Limestone; fine grained and of a light drab color	17	23
(19)	Shale; calcareous with fossil corals, etc., of a dark drab color	23	111
(18)	Limestones, shales; the limestones are of a light drab color and have in them streaks of blue limestone and of light colored shales	111	147
(17)	Limestone; of a light drab color and white opaque colors with streaks of iron rust, which leave insoluble residue in hydrochloric acid	147	314
(16)	Limestone; of a blue color and with a fracture something like flint	314	402
(15)	Limestone; hard and fine grained and of a bluish brown color	402	439
(14)	Limestone; flaggy in the upper part, with iron rust in places, light color	439	502
(13)	Limestone; fine grained, blue	502	556
(12)	Limestone; light blue color, with iron rust stains	556	629
(11)	Black shales; Devonian	629	646
(10)	Limestone; shaly, light gray color, carrying the *first gas* at 652 ft.	646	662
(9)	Limestone; blue	662	1005
(8)	Limestone; light color with glistening particles in some of it, carrying near its bottom the *second gas*	1005	1094
(7)	Limestone; of a drab color	1094	1228
(6)	Limestone; light color	1228	1266
(5)	Limestone; dark color	1266	1300
(4)	Limestone; drab color	1300	1400
(3)	Limestone; light blue color, *black oil* at bottom	1400	1500
(2)	Limestone; gray color	1500	1689
(1)	Sandstone; calciferous and of a light gray color, to the bottom of the well	1689	1730

* Adapted with corrections from Report on the Valley Regions of Alabama, by Henry McCalley, Part I, p. 254, Alabama Geological Survey, 1896.

Of the above log (1) is probably the Knox dolomite, (2) to (10) inclusive are the Trenton limestones, (11) is the Devonian black shale, (12) to (16) inclusive are the Lauderdale cherts, (17) is the Tuscumbia limestone, and from (18) to (20) inclusive are the formations of the Hartselle group. The local reports were that both oil and gas were found in this well in small quantities, but not of sufficient quantities to be of commercial value. No subsequent tests have been made in the immediate vicinity of this well.

PICKENS COUNTY.

GEOLOGY.

The Coal Measures, the only possible source of oil in Pickens County, are covered by from 200 to 1,200 feet of Cretaceous strata lying unconformably over them (Fig. 18). This covering effectually conceals all favorable structure that might be developed in the Coal Measures, so any location that might be made would be wholly at random and the chances for production very remote. However, the Coal Measures in this county might well become a productive petroliferous series as the area is sufficiently removed from the center of deformation and metamorphism for oil to accumulate in considerable quantities.

SAINT CLAIR COUNTY.

GEOLOGY AND STRUCTURE.

Saint Clair County, lying in the Coosa Valley region, is roughly bisected by the Coosa coal field. On either side the older Paleozoic formations are exposed, showing sharp folding and widespread faulting. Since these areas can be eliminated, and there only remain the synclinal troughs of the Coosa and the Cahaba coal fields, only the northern tip of the latter extending into the county, where gas accumulation would be possible.

DEVELOPMENT.

Oil seeps have been reported in the Coosa field at Cook's Springs, and some unimportant shows of oil and gas have been encountered in making tests for coal and iron, but considering the unfavorable structure and rather intense deformation there is nothing to warrant the expenditure of considerable sums in making tests solely for oil and gas.

SHELBY COUNTY.

GEOLOGY AND STRUCTURE.

The Carboniferous formations underlie the greater part of Shelby County. The structure of this area is generally synclinal, though a rather pronounced faulted anticline bisects the Coosa coal field, exposing the underlying Lower

Carboniferous limestones and separating the Coal Measures into two distinct strips. To the south of this area of Carboniferous strata the older formations appear, highly folded and faulted, and consequently of no value as a commercially productive series. In the western corner of the county the Coal Measures reappear in the Cahaba coal field, separated from the Coosa field by a deeply eroded and faulted anticline. The county, therefore, offers no possibilities, except that of gas production in some of the numerous minor structures of the area underlain by the Carboniferous strata. (Sections 18-24, Plate II.)

DEVELOPMENT.

Only small traces of oil have been encountered in the diamond drill and other wells bored in the county. Gas shows have been more frequently found, and have occasionally been of a very promising character.

TALLADEGA COUNTY.

GEOLOGY AND STRUCTURE.

This county was not included in the impossible territory, because of the remote possibility of small gas accumulations in the highly folded and faulted Paleozoic formations, especially the Knox dolomite. All of the southeastern third of the county is underlain by the crystallines and the accumulation of either gas or oil is impossible in this part of the county.

TUSCALOOSA COUNTY.

GEOLOGY.

Throughout the southern and western part of Tuscaloosa County the Coal Measures are concealed by the gravels, sands and clays of the Tuscaloosa formation. In the northern part of the county, likewise, the Coal Measures are extensively covered, along the major divides, by this formation and the Lafayette gravels. It is only throughout about one-fourth of the county, therefore, that the Coal Measures are exposed sufficiently to enable the geologist to determine the local structure. In the southeastern part of the county

the lower Paleozoic formations down to the Cambrian are exposed along the axis of the Jones Valley anticline.

STRUCTURE.

The principal structural feature of the county is the Jones Valley anticline, steeply inclined and faulted on its northern side, a typical asymmetric Appalachian fold. This fault marks the southern boundary of the Warrior coal field and also the southern limit of possible oil territory in Tuscaloosa County. The Coal Measures are locally folded, and parallel undulations are set up alongside the major Appalachian folds. Along the eastern line of the county the southern end of the Brown's Valley anticline can be traced out as a gentle warp in the Coal Measures. Throughout the whole area underlain by the Coal Measures folding seems to be abundant, where the series is sufficiently exposed to determine the structure. Scarcity of outcrops in the northern part of the county prevents the working out of structure in detail, but indications of folding are widespread. The northern and western part of the county is to be considered the most favorable for gas or oil accumulation as the fixed carbon in the coal in this area runs lower than closer in to the center of the region of disturbances. (Sections 27-28, Plate II.)

DEVELOPMENT.

Numerous wells have been drilled in the county, some of them for water, and others for oil and gas. Still others have been drilled in testing for coal and iron. In 1905 a well was drilled by the City of Tuscaloosa near the Court House, to the depth of 1,511 feet. No reliable record was kept of this well but the formations as reported are the usual succession of sandstones, shales and conglomerates of the Coal Measures. This well got a good flow of water, but no oil or gas shows were reported. Two wells were drilled in 1915 by Frederick Morck at Lock 15 in the Warrior River. The first was 900 feet deep and the second 1,900 feet, the latter encountering near its bottom a hard, black, limy shale, with faint traces of oil.

At the present time portions of the county are being examined by the geologists of one of the larger companies and acreage is being blocked up in expectation of drilling.

WALKER COUNTY.

GEOLOGY.

Walker County lies in the Plateau Region and can be included in its entire extent in the Warrior coal field. The Coal Measures do not reach the great thicknesses that are represented in Jefferson and Tuscaloosa, but along the southern line of the county as much as 2,000 feet of these sediments remain unremoved by erosion. In the northern part of the county the upper beds have been eroded, leaving about 1,000 feet of the lower strata still intact.

In the western and northwestern part of Walker County the Coal Measures are extensively covered by the gravels and clays of the Tuscaloosa and Lafayette formations. These unconsolidated sediments are usually confined to the upland areas between the streams where they effectually conceal the structure of the Coal Measures below.

STRUCTURE.

The general structure of the county is synclinal, the general dip being to the south, except where the strata are turned up abruptly along the southwestern line of the county to form the northern limb of the Brown's Valley anticline. Upon this normal south-dipping monocline there are developed numerous minor structures, which as in other parts of northern Alabama, show two general trends, northeast and southwest. At the intersection of these two series closed structures would be formed which would be favorable points for oil prospecting. (Section 18, Plate II.)

The sixty per cent. isovolve (Fig. 15) passes approximately through the center of Walker County from north to south. In Texas this sixty per cent. isovolve constitutes the dead line east of which no large accumulations of oil occur. If this holds good for Alabama only the western part of Walker County could be classed as possible oil territory, and in the eastern half where the fixed carbon is over 60 per cent. only accumulations of gas could be expected. This has been borne out by past development in the county, for only gas has been found in large quantities, though small shows of high grade oil have been encountered. The heavy oil found at Cordova is an exception.

DEVELOPMENT.

The center of development in Walker County has been around Jasper, where the Pennsylvania Oil and Gas Company drilled in 1911-1912 a number of tests locally known as the Shannon wells. Three of these wells at Jasper got gas and after being shot were estimated at about 150,000 cubic feet a day each. The producing horizon in each case was the Hartselle sandstone, encountered in this locality at about 1,800 feet. Small showings of oil were found in the Coal Measures and gas or a flow of fresh water in the Millstone Grit. The No. 1 well on the Long estate got a good show of gas in the Hartselle sandstone at 1,792 feet and was continued to 3,000 feet without other shows. This well encountered several red limestones (possibly sandstones) near the bottom and then passed into a black limestone, probably the Trenton. The log is given herewith:

Pennsylvania Oil & Gas Company No. 1 Well, Long Estate.

Located in N.W. ¼ of N.W. ¼ Section 22, Township 14, Range 7.

		Feet	*Feet*
PENNSYLVANIAN Coal Measures	Conductor	13	
	Shale, black	13 to	50
	Sand, white	50	
	Artesian water	65	
	Bottom sand	150	
	Shale (dark)	150 to	375
	Water, sand, gas, show	375	
	Of black oil	390	
	Water, gas and show green oil	447 to	452
	Bottom sand	494	
	10-inch casing	502	
	Lime and shale with occasional sand shell a few inches thick to	652	
	Sand	652	
	Enough water to drill with (10 bailers)	661	
	Break slate	728 to	734
	Bottom sand	860	
	Slate black	860 to	900
	Sand, white	900	930
	Shale (gray)	930	987
	Sand, white, and 10 more bailers water at	1022	
	More water (8¼-inch casing)	1123 to	1150
	Bottom sand	1272	
MISSISSIPPIAN Upper Bangor	Red shale	1272	1278
	Lime	1278	1300
	Slate (white)	1300	1306
	Lime	1306	
	6⅝-inch casing	1309–6	
	Lime, white, very hard	1309	1321
	Lime, black	1321	1330
	Lime, white, hard	1330	1771
	Slate, black	1771	1791
	Sand (steel-lime line)	1791½	
Hartselle	Top very hard with nice showing petroleum gas, enough to run drilling well (Hartselle 100 feet thick).		
Lower Bangor	Bottom	1891	
	Lime, white, hard	2068	
	Bottom of lime	2090	
	White lime	2100	
Fort Payne Chert	Black lime	2268	
	Lime shell	2335	
	Slate	2343	
	Lime	2368	
	Lime	2400	
	Lime	2465	
	Lime	2580	
Devonian (?)—Lime, shell and slate		2600	

		Feet	Feet
Silurian Clinton	Red lime at top	2610	
	Red lime bottom	2790	
	Red slate	2710	
	Red lime	2720	
Ordovician Trenton	Black lime shell	2726	
	Red slate at 14 feet	2726	to 2740
	Black lime	2740	to 2850
	Break of red slate 22 feet	2850	to 2872
	Black lime	2862	to 3004
	(3003-9 actual depth.)		
	Black chocolate and gray.		
	Shut down May 9th, 1911.		

The Shannon wells were drilled in close proximity to each other and their logs are very similar. The log of well No. 3, one of the three producers, represents a typical section and is as follows:

Record of Well No. 3 of Pennsylvania Oil and Gas Company.

		From Feet	To Feet
Coal Measures	Clay, yellow, soft	0	14
	Slate, black, soft	14	65
	Sand, black, hard	65	80
	Sand and shells	80	110
	Sand, white	110	160
	Sand, black	160	180
	Slate and shells	180	385
	Lime, white	385	398
	Sand, white	398	405
	Lime, white	405	440
	Lime and slate	440	600
	Lime, white	600	648
	Lime and slate	440	600
	Lime, white	600	648
	Sand, white	648	858
	Slate, white	858	865
	Sandy lime, white	865	940
	Coal	940	945
	Lime, black	945	1005
	Big Injun sand	1005	1270
	Slate and shells	1270	1285
	Red rock	1285	1300
	White lime	1300	1320
	Slate, black	1320	1330
Mountain Limestone Bangor	Lime, black	1330	1340
	Limestone	1340	1660
	Slate and shells	1660	1740
	Slate	1740	1800
	Jasper or Hartselle sand	1800	1812
	Gas.		
	Well finished at 1812.		

The same company drilled a 4,000-foot well near Calumet some two and a half miles south of the Shannon wells. Traces of oil were found in the Hartselle sandstone and in the Tuscumbia limestone. The log as given below is rather indefinite, but the well undoubtedly reached the Trenton limestone and probably the upper strata of the Knox.

Calumet Well, Pennsylvania Oil and Gas Company.

		DEPTH	
		Top *Feet*	*Bottom* *Feet*
COAL MEASURES	Conductor	12	.....
	Hole full of water	35	.....
	Slate and shale	112	.....
	Coal	112	115
	Slate and shale	115	125
	Sand	125	220
	Slate and shale	220	495
	Sand	495	535
	Sandy lime	535	560
	Slate and shale	560	675
	Lime	675	690
	Sand	690	785
	Slate	785	800
	Sandy lime	800	880
	Red sand	880	900
	Sandy lime	900	940
	Slate	940	955
	Sandy lime	955	1030
	Slate and shale	1030	1065
	Sandy lime	1065	1080
	Sand	1080	1100
	Sandy lime	1100	1195
	Sand	1195	1225
	Sandy lime	1225	1315
	Sand	1315	1345
	Sandy lime	1345	1385
Bangor	Slate	1385	1405
	Lime, white	1405	1455
	8-inch casing at 1452.		
	Slate	1455	1460
	Lime, white	1460	1815
	Reduced hole at	1755	
	Lime, black	1815	1873
	Sand and shale	1873	1878
	Slate	1873	1894
Hartselle	Top of sand 3	1894	2000
	Slate and shale	2000	2050
	Brown shale	2050	2095

		DEPTH	
		Top	*Bottom*
		Feet	*Feet*
Tuscumbia	Lime, white	2095	2260
	Lime, dark	2260	2278
	Sand, dark, with show of oil	2278	2284
	Lime, dark	2284	2340
	Sand, brown	2340	2350
	Limestone, sand, dark	2350	2395
	Slate	2385	2400
	Black lime	2400	2425
	Slate and shale	2425	2525
Lauderdale Chert	Lime, pink	2525	2545
	Lime, dark	2545	2595
Devonian	Slate, dark	2595	2675
Silurian	Lime, red	2675	2780
	Lime, dark	2780	2875
Trenton	Slate	2875	3000
	Lime, white	3000	3690
	Blue lime	3690	3730
	White lime	3730	3890
	Gas at	3854	
Knox (?)	Sandy lime	3920	4015

The Pennsylvania Oil and Gas Company also drilled a hole at Oakman, some ten miles southwest of Jasper. The Hartselle sandstone was here encountered at about 2,200 feet and gave a strong odor of oil and gas. The well was continued to 2,775 feet, stopping at about the base of the Lauderdale chert. The log as given shows that traces of oil and gas were found at various depths.

Log of Well No. 2 of the Pennsylvania Oil & Gas Company, Oakman, Alabama.

	Formation	*Color*	*Soft or Hard*	*Feet*		*Feet*
	Clay	Brown	Soft	to 13		
	Conductor on solid rock.					
	Slate	Black	Soft	13	to	23
	Water at 23.					
	Shale and sand	White	Hard	23	to	53
	Water at 50 feet.					
	Lime, shells and slate	Black	Hard	53	to	90
	Coal	Black	Soft	90	to	92
	Slate	White	Soft	92	to	110
	Sand	Blue	Hard	110	to	170
	Sand	White	Hard	170	to	230
	Sand	Dark	Hard	230	to	270
	Slate	Black	Soft	270	to	330
	Slate and shell	Black	Soft and Hard	330	to	374
	Coal	Black	Soft	374	to	377
	Slate	Black	Soft	377	to	560
	Sand and lime	Black	Hard	560	to	575
	Sand	White	Hard	575	to	655
	Light gas show.					
PENNSYLVANIAN Coal Measures	Slate and shell	Black	Soft	655	to	720
	Sandy lime	Dark	Hard	720	to	735
	Sand	Dark	Hard	735	to	790
	Slate	Black	Soft	790	to	850
	Slate and hard shell	Black	Soft and Hard	850	to	885
	Sand	White	Hard	885	to	925
	Slate	Dark	Soft	925	to	930
	Sand	Gray	Very hard	930	to	950
	Rainbow of oil on rope at 954, light show.					
	Sand	White	Soft	950	to	1000
	Lime	Black	Very hard	1000	to	1030
	Slate	White	Soft	1030	to	1060
	Gritty lime	Black	Hard	1060	to	1080
	Slate	Black	Soft	1080	to	1100
	Slate	White	Soft	1100	to	1120
	Slate	Black	Soft	1120	to	1185
	Sand	White	Soft	1185	to	1200
	Sand	Dark	Hard	1200	to	1245
	Slate	Black	Soft	1245	to	1280
	Slate and shell	Black	Hard	1280	to	1295
	Sand	Yellow	Very hard	1295	to	1415
	Slate	Dark	Soft	1415	to	1450
	Lime	White	Hard	1450	to	1510
	Slate and shells	Black	Soft and Hard	1510	to	1570
	Sand	White	Hard	1570	to	1600
	Light show of oil at 1572.					
	Slate and shells	Yellow	Very hard	1600	to	1750
	Sand	White	Hard	1750	to	1795
	Sand	Black	Soft	1795	to	1800
	Sand	White	Hard	1800	to	1845
	Sand	Yellow	Hard	1845	to	1855

	Formation	Color	Soft or Hard	Feet	Feet
MISSISSIPPIAN Bangor	Sand	Black	Hard	1855 to	1870
	Lime and sand	Black	Soft	1870 to	1900
	Lime	Black	Hard	1900 to	1910
	Sand	Dark	Hard	1910 to	1940
	Slate and sand	Dark	Soft and Hard	1940 to	1985
	Slate	Dark	Soft	1985 to	2005
	Caving at 1985.				
	Slate	Dark	Soft	2005 to	2049
	Slate	Dark	Soft	2049 to	2104
	Slate, lime and shells	Dark	Soft and Hard	2104 to	2135
	Lime	White	Hard	2135 to	2225
Hartselle	Sand	Light and dark	Hard	2225 to	2295
	Lime	Black	Hard	2295 to	2385
	Strong odor of oil at 2365.				
	Slate and shell	White	Hard	2385 to	2405
	Slate	Black	Soft	2405 to	2425
	Sand	Blue	Hard	2425 to	2450
	At 2430 strong odor of oil and gas.				
	Slate	Black	Soft	2450 to	2455
	Sand	Blue	Hard	2455 to	2480
	Lime	Black	Hard	2480 to	2485
	Sand	Black	Hard	2485 to	2525
	Slate	Black	Soft	2525 to	2650
Lauderdale Tuscumbia	Lime	Black	Hard	2650 to	2660
	Dark reddish tint.				
	Lime	White	Hard	2660 to	2690
	Sand	Black	Hard	2690 to	2705
	Lime	White	Hard	2705 to	2775

January 9, 1912, broke shaft on bed plate of engine, leaving tools in hole. Shipped in engine and still fishing for tools February 12, 1912. Stopped work that day.

The Tennessee Coal, Iron and Railroad Company drilled a test well in 1911 near Nauvoo, in the northwestern corner of the county, to the depth of 1852 feet. The Black Creek coal seam was found at 97 feet and a faint show of oil in the Tuscumbia at the bottom of the well.

Record of Test Well No. 3, Near Nauvoo, Alabama.

Location: Near center of Section 16, Township 12 South of Range 9 West.
Stopped drilling September 23, 1911; depth, 1852 feet.
Record by C. S. Blair.

		Thickness Feet.	*Depth Feet.*
PENNSYLVANIAN Coal Measures	Surface	7	7
	Sandstone	35	42
	Slate	6	48
	Lime (probably hard black slate)	16	64
	Sandstone	10	74
	Slate	20	94
	Coal (Black Creek seam)	*3*	*97*
	Slate	3	100
	Sandstone	6	106
	Slate	6	112
	Sandstone	8	120
	Sandstone, sharp grained	20	140
	Slate	145	285
	Sandstone	45	330
	Slate	10	340
	Sandstone	18	358
	Lime (probably slate)	15	373
	Slate	77	450
	Lime (probably slate)	170	620
	Millstone Grit Formation:		
	Sandstone	65	685
	Lime (probably slate)	25	710
	Sandstone	275	985
	Sandstone, slate seams	55	1040
MISSISSIPPIAN	Bangor Limestone:		
	Limestone, pure, light colored	370	1410
	Slate	25	1435
	Limestone	90	1525
	Hartselle Sandstone:		
	Sandstone, fine grained	12	1537
	Sandstone, coarse grained	89	1626
Tuscumbia	Slate, soft black	56	1682
	Limestone, siliceous	33	1715
	Slate, soft	102	1817
	Limestone, dark colored, very fossiliferous, petroleum odor at base	35	1852

In December, 1916, a flurry of excitement was caused throughout Alabama by the report of the bringing in of an oil well at Barney, near Cordova. At the time the production of this well was given at a variety of exaggerated figures. The well, drilled by Oklahoma parties, got a small show of heavy oil at about 830 feet (26.5° gravity Baume) and after being shot was drowned out by a flow of salt water. This show of heavy oil would indicate that a small

pocket of residual oil, the lighter more volatile constituents of which had previously migrated off, had been entrapped at this point.

WINSTON COUNTY.

GEOLOGY.

The areal geology of Winston County is much the same as that of Marion County, except that the Tuscaloosa formation is much less extensive and confined to the western part of the county, and along the northern line of the county there are a few spots where the streams have cut through the Coal Measures and exposed the Sub-carboniferous. Most of the surface of Winston County is, therefore, formed by the Coal Measures, varying in thickness from a thousand feet or more in the southern and southwestern part of the county to where they are completely eroded along the northern line. The topography is fairly rugged, very precipitous valleys being developed by some of the streams in the lower sandstones of the Coal Measures, which have in some cases given rise to "rock-houses" and natural bridges (Fig. 20).

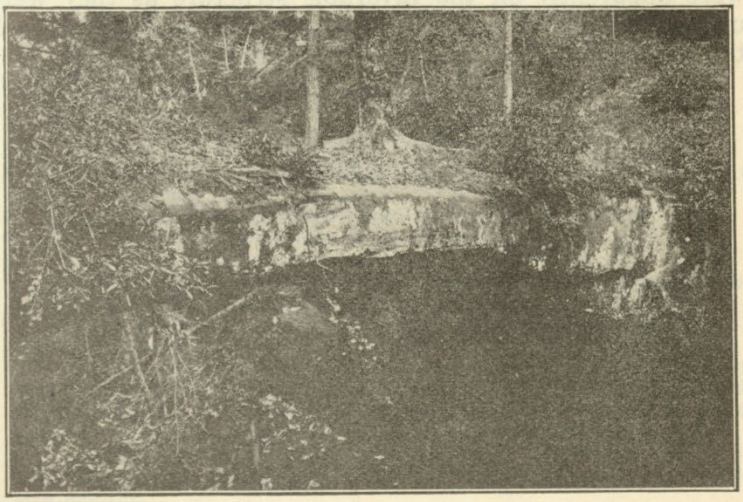

FIG. 20. A natural bridge formed by a headward erosion giving rise first to a "rock-house," which subsequently caved in to form the bridge. Near Natural Bridge, Winston County. (Photo by R. M. Harper.)

STRUCTURE.

Exposures are sufficiently numerous throughout the county to determine the structure with fair accuracy. The predominant type of fold is the northwest-southeast wave or gentle undulation that is so frequently developed in northwestern Alabama. Occasionally folds paralleling the Appalachian trend are also to be found. The gas well at Haleyville is apparently located upon one of these northwest-southeast undulations. The subsequent tests were unfortunately not made along this trend and were unproductive.

The coal from Winston County shows a comparatively low percentage of fixed carbon, an indication that the area has not been subjected to intense compression or deformation, but the occurrence of gas at Haleyville apparently indicates that what deformation has occurred has been sufficient to bring about gas rather than oil accumulation.

DEVELOPMENT.

The principal development in Winston County has been at Haleyville where several wells were drilled in 1911-1912, one of which got gas in large quantities. The other wells were apparently off the favorable structure as they were unproductive. An accurate log was made of the first well, the gasser, which is as follows:

Well No. 1, Haleyville.

Elevation: 205 feet below railroad at Haleyville—(Elliott).

Formation	*Character of Material*	*Thickness*	*Depth*
Recent	Surface soil and sand	9	9
Millstone Grit	Sandstone, white	151	160
	Shale, non-calcareous	100	260
	Sandstone and shale	85	345
	Sandstone and some shale	270	615
Bangor	Limestone, chiefly oolitic	375	990
Hartselle	Shale, black, calcareous	150	1140
	Sandstone, fine carcareous	180	1320
	Shale, gray to black, calcareous	170	1495
Tuscumbia	Limestone, cherty in part	150	1645
Lauderdale	Chert and limestone	90	1735
Devonian	Shale, black, pyritic, oily	25	1760
Niagara	Limestone, greenish white	15	1775
Clinton	Shale and limestone, red and green	260	2035
Trenton	Limestone and trace of shale	15	2050
	Shale, black to gray, calcareous	165	2215
	Limestone and shale, ferruginous	20	2235
	Shale and limestone	55	2290
	Limestone, gray to white	625	2915
Knox	Dolomite, gray, crystalline. *Gas*	25	2940
	Limestone, buff, compact	5	2945
	Dolomite, gray, crystalline. *Gas*	15	2960
	Limestone and black, oily shale	20	2980
	Dolomite, gray, crystalline	2	2982

WATER.

Fresh water to 620 feet.
Salt water from 1470 to 1620 feet.
Salt water (little) at 2725 feet.
Salt water (abundant) at 2980 feet.

GAS AND OIL.

Traces of oil and gas in the Hartselle sandstone and shale from 1145 feet to 1350 feet.

Odor of oil in Lauderdale chert, from 1645 feet to 1735 feet.

Traces of oil in Devonian shale, from 1735 feet to 1760 feet.

Odor of oil in Niagara limestone, from 1760 feet to 1775 feet.

Traces of oil and gas in Clinton shale from 1775 feet to 1845 feet.

Odor of oil in Trenton shale from 2075 feet to 2185 feet.

Gas (about 600 pounds) in Knox dolomite, from 2920 feet to 2945 feet, and from 2950 feet to 2960 feet.

The gas in the Knox was struck September 20, 1911, and November 1, 1911, after the salt water below 2980 had been effectually shut off, by plugging with lead and concrete, the well was shot in the gas horizon with 160 quarts of solidified nitro-glycerine. The flow of gas greatly and permanently increased. The closed pressure of the well is very high. The flow of gas was practically free for the first five months.

Another test was made about the same time by the Woodward Oil and Gas Company near Double Springs in the center of the county.

Well No. 3, Near Double Springs.

SUMMARY RECORD.

Formation	*Character of Material*	*Thickness*	*Depth*
Coal Measures and Millstone Grit	Sandstone and shale	670	670
Bangor	Limestone and shale	460	1130
Hartselle	Sandstone	180	1310
	Shale and limestone	150	1460
Fort Payne	Limestone and chert	310	1770
Devonian	Black shale	20	1790
Clinton	Red and green limestone and shale	150	1940
Trenton	Shale, limestone and shale	40	1980
	Limestone	170	2150
	Shale	30	2180
	Limestone	260	2440

PART II

COASTAL PLAIN AREA

BY

J. EDWARD BRANTLY

PART II

COASTAL PLAIN AREA

By J. Edward Brantly.

INTRODUCTION.

IN STUDYING the Coastal Plain area of Alabama with reference to its possibilities of producing petroleum in commercial quantities, no attempt has been made to give the relative values of the logical subdivisions, except in a very broad manner. This has been done primarily to prevent the useless expenditure of the necessary sums for prospecting in areas where it seems improbable that commercially profitable deposits of oil and gas will be discovered. Because of the fact that there has been comparatively little testing for oil in the southern half of Alabama, it is necessary to present the conditions primarily from the information that can be gathered along the surface terranes of the various formations which compose the Coastal Plain. Each formation has been described in sufficient detail to allow those interested in the subject to draw their own conclusions without the necessity of making studies in the field. At the same time these descriptions are presented in such a manner that those studying the field conditions will be readily able to recognize the horizon in which they are working. The formations which are considered to have the most favorable outlook for production are presented briefly in the latter part of the report accompanied by the logs of certain wells that have been drilled in the Coastal area. The known structures in the Coastal Plain are discussed with the idea of broadly delimiting them for the assistance of those working in the field rather than for the purpose of describing areas in which exploration is justified.

The writer wishes to acknowledge the great assistance given him by Dr. Eugene A. Smith, State Geologist of Alabama, both through the medium of his writings on the

Coastal Plain area and consultations with him during the preparation of this report, also it is wished to acknowledge the use of publications by D. W. Langdon, L. C. Johnson, L. W. Stephenson, G. C. Matson, E. W. Berry and C. W. Cooke. Proper reference is given to these authors and their publications where data have been secured from them.

SUMMARY.

As a result of the study of the possibilities of petroleum in the Coastal Plain area, that part of the State has been divided into several districts, each of which has conditions peculiar to itself. The possible sands have been studied broadly, and the structural deformation considered to the extent permissible with the data at hand. It is found that the only structure that has been tested did not yield oil, nor did the tests lend much encouragement to further exploration even though the most promising area of the anticline has not been drilled through the chalk. In Eastern Alabama it was found that the possible sand horizons should be considerably thicker than in the western part of the State, and, therefore, the chances for success proportionally greater. Several folds that give promise of proving to be good structures are outlined: the Lower Peachtree Anticline, the Beatrice Anticline and the Geneva fold. Also the Hatchetigbee and Jackson structures, which are more completely described elsewhere, are considered. In conclusion the work has shown that there are areas in which are structures, capable of acting as traps for the accumulation of oil, overlying sands that may be petroliferous and are within easy reach of the drill.

LOCATION.

The Coastal Plain area of Alabama is all of that portion of the State between the Fall Line, where the streams run out of the hard rock and into the soft rock countries, and the Gulf of Mexico on the south and the Mississippi line on the west. In area it comprises about two-thirds of the total area of the State. Along the northern border of the plain area there is only a thin mantle of the Coastal Plain material through which the streams have cut into the older Coal Measures and metamorphosed rocks below, in such a manner that no definite line can be drawn separating the

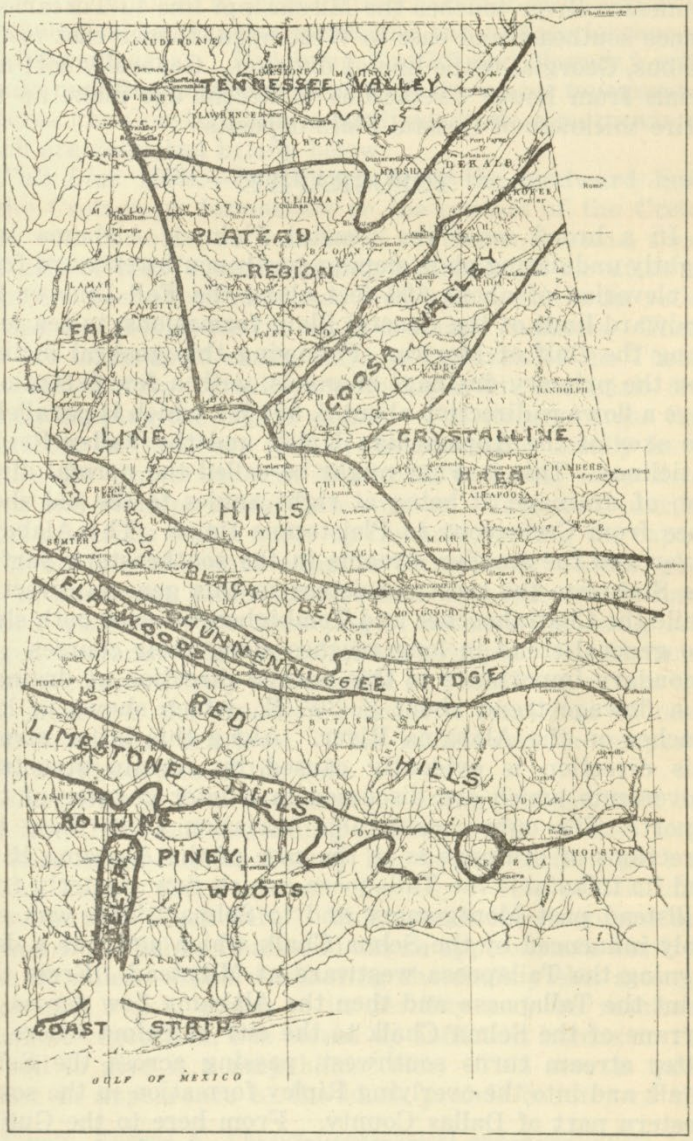

FIG. 21.—Topographic subdivisions of Alabama.

provinces. Roughly a line drawn from the point where the Tennessee River touches the Mississippi line to Tuscaloosa, thence southeast and east to Wetumpka, thence east to Columbus, Georgia, is the line of division. Generally soft materials from Lower Cretaceous to Recent age make up the entire thickness of Coastal Plain deposits.

TOPOGRAPHY.

In a broad sense the Coastal Plain of Alabama is a slightly undulating plain sloping gently southwestward from an elevation of about 600 feet along the Fall Line or the landward limit of the Coastal Plain formations, to sea level along the Gulf of Mexico. Following this general inclination the primary drainage channels, with a few exceptions, have a flowage direction about S. 30° W., which is parallel to the axes of the Appalachian Uplift and the Valley Region anticlines. This is what might be called the normal direction of drainage, it being at right angles to the old shore lines from Cretaceous to Pleistocene times. The Alabama River and the smaller streams in the southeastern part of the State are the most consistent in this general direction while the Chattahoochee and Tombigbee-Warrior both show the general trend in long reaches along their courses. Of secondary importance to this normal direction of drainage is a flowage trend about S. 30° E., which shows in long reaches on the Alabama River. Along this latter stream this direction is evidently caused by certain structural movements which are discussed in a later chapter of this report. The only considerable variation from these two directions of drainage is in the case of the Alabama River and its tributary, the Tallapoosa, which flow westerly from Millstead past Montgomery and to Selma. This was possibly influenced by the Selma Chalk which acted as a dam, turning the Tallapoosa westward at Millstead. From that point the Tallapoosa and then the Alabama flow across the terrane of the Selma Chalk to the city of Selma where the latter stream turns southwest, passing across the Selma Chalk and into the overlying Ripley formation in the southwestern part of Dallas County. From here to the Gulf of Mexico the southwesterly direction is maintained.

The Coastal Plain of Alabama while being on the whole a gently sloping country is readily subdivided into a number

of areas having separate and distinct topographic features which are imparted to them by the character of materials of the geological formations composing the surface terrane of the different areas. Following Smith* and Harper,† with certain modifications consistent with the major topographic features, the Coastal Plain is subdivided into nine provinces which are described briefly below:

Fall Line Hills.—Southward from the landward limit of the Cretaceous formations or the contact of the Cretaceous with the older formations of northern Alabama, there is a belt of hilly country having a maximum elevation of about 600 feet above mean sea level and a maximum relief of near 400 feet above the main drainage channels. These hills are made up of sands, clays and gravels of the Tuscaloosa and Eutaw formations with Lafayette materials frequently capping the higher points. The streams cross this area from the northern part of the State and usually have, besides the University and Northport terraces, wide flood plains and swamps along their courses. The sandy nature of the materials which make up the area, having the capacity of holding abundant supplies of meteoric waters, give rise to numerous small streams and branches which have further assisted in the dissecting of the area into steep and rugged surfaces. In the northwestern part of Alabama where a comparatively thin mantle of Tuscaloosa covers the Coal Measures the elevation reaches a maximum of near 1,000 feet above sea level. This is, however, a comparatively small portion of the belt.

Black Belt or Prairie Country.—Lying next south of the Fall Line Hills and extending slightly south of east from the Mississippi-Sumter County line to the eastern part of Bullock County there is a belt of gently rolling prairie land known as the "Black Belt." This area is the entire surface terrane of the Selma Chalk and has an approximate width of 15 to 20 miles. Upon weathering the chalk yields a tough yellow soil which, owing to its fertility and the resultant abundant vegetation, has stored up sufficient humus in the top soil to give it a deep black color. This area is quite similar in appearance to the black prairie country of the

*Smith, Eugene A., Physico-Geographical and Agricultural Features of Alabama, Tenth Annual Census of the United States, Vol. VI, 1880.

†Harper, Roland M., Economic Botany of Alabama, Part I, Monograph 8, Geological Survey of Alabama, 1913.

Eagle Ford, Austin Chalk and Taylor marl districts in Texas. The prairie belt in Alabama is gently rolling with occasional more or less prominent hills resulting from local indurated parts of the chalk.

Chunnennuggee Ridge.—Extending across the State from the Tombigbee River to the Chattahoochee in southern Russell and northern Barbour Counties there is a strip of country characterized by a rather hilly topography, which is in effect a ridge supported by the indurated ledges of the Ripley formation. The name is derived from Chunnennuggee Ridge south of Union Springs. Along the Chattahoochee this subdivision occupies the eastward extension of the Black Belt and is very similar in all features except the nature of the soil which is a tough yellow clay in the Ripley area. The hills of this belt are frequently very steep and reach an elevation of 300 feet above the level of the main drainage channels. A good example of the type country is in the northern part of Wilcox County.

Post-Oak Flatwoods.—The Flatwoods extend in a narrow belt southeastward from Sumter County to near the Louisville and Nashville Railroad in Butler County north of Greenville. The area is generally flat to gently rolling with a tough reddish clay soil derived from the underlying Sucarnochee clays. Post Oak is the predominating growth.

Southern Red Hills.—This belt, extending entirely across the State, composes practically all of that area in which the formations of Eocene age come to the surface and has a rather uniform width of near 35 miles but exceeding this somewhat in the eastern part of the State. In the eastern part of the belt the name here used is descriptive of the topography while in the area west from Butler County the belt is composed of several east-west ridges supported by the indurated parts of the formations which come to the surface. The most typical of these ridges are the Grampian Hills south of Camden and the Tallahatta Hills in Clarke and Monroe Counties. The first of these is supported by the indurated beds of the Nanafalia formation while the latter is the result of the calcedonized layers in the upper part of the Tallahatta Buhrstone. In broader consideration these ridges are cuestas with the steep scarps on the north and the gentle dip slopes to the southward. However, the highly dissected nature of both ridges obliterates the actual resemblance to true cuestas. The hills are generally very steep

FIG. 22.—CHATTAHOOCHEE RIVER SECTION.

Based on Section made by D. W. Langdon.

AGE	SER.			
Recent and Quaternary		Pleistocene	First Bottom	River flood plain and stream gravels and sands and red, chocolate and black silts and clays. Thickness 0-40 feet.
			Columbia Group Terraces: Northport Terrace (2d) University Terrace (3d)	Sands, clays and gravels of second and third stream terraces. (Satilla and Okefiinokee of Georgia), 50 to 60 and 100 to 150 feet above stream levels.
		Pliocene	Lafayette Group	Gravels, sands and clays resting on all formations from the crystalline and Paleozoic rocks to and including those of Pliocene age.
				Some of the sands, clays and gravels possibly represent deposits of early Pliocene age in southeast Alabama.
Cretaceous		Upper	Beds present in Florida but not as far north as Alabama.	
			(Unconformity)	ber 150 to 200 feet thick at top. Beds generally greenish. Fossiliferous. Thickness, 550 to 600 feet.
		Lower Cretaceous or Comanchean	Tuscaloosa formation	Langdon placed the continental sands and clays below the Eutaw in the Tuscaloosa formation (Upper Cretaceous) while Stephenson on later study considers them to be of Comanchic or Lower Cretaceous age. Thickness, about 350 feet.

	Bashi formation	*costa*. Langdon gives one ... in middle part. 18 feet of sandy limestone at base. Thickness, about 45 feet.
Eocene	Wilcox Group	
	Tuscahoma formation	Light yellow and gray sandy clays with large smooth boulders, more sandy in upper portion. Thickness, about 170 feet.
	(Nanafalia formation (Unconformity)	Calcareous sands with boulders; glauconitic sands, argillaceous and cross-bedded sands and claystone. The calcareous and glauconitic sands highly fossiliferous in lower part with occasional fossiliferous beds in upper portion. *Gryphaea thirsae* most characteristic fossil; also *Venericardia planicosta*, *Turritella mortoni*, *Ostrea compressirostra*, etc. Thickness, about 175 feet.
Upper Cretaceous or Gulf Series	Midway formation (Clayton Limestone)	White Calcareous sands, soft white massive limestone, hard sandy semi-crystalline limestone in Georgia. Fossils *Ostrea pulaskensis*, *Ostrea crenulimarginata*, *Turritella humerosa and mortoni*, etc. Thickness, about 200 feet. 10 feet of sandstone under limestone.
	(Unconformity)	
	Ripley formation	Glauconitic and blue sands, clays and sandy clays with occasional hard impure ledges of limestone. Marine with numerous fossils. *Exogyra costata*, *Ostrea larva*, *O. plumosa*, *Inoceramus*. Thickness estimated to be about 950 feet.
	Eutaw formation	Sands and clays of marine origin. Tombigbee sand member 150 to 200 feet thick at top. Beds generally greenish. Fossiliferous. Thickness, 550 to 600 feet.
	(Unconformity)	
Lower Cretaceous Comanchean	Tuscaloosa formation	Langdon placed the continental sands and clays below the Eutaw in the Tuscaloosa formation (Upper Cretaceous) while Stephenson on later study considers them to be of Comanchic or Lower Cretaceous age. Thickness, about 350 feet.
Cretaceous		

Based on Section made by D. W. Langdon.

Recent and Quaternary	Pleistocene	First Bottom	River flood plain and stream gravels and sands and red, chocolate and black silts and clays. Thickness 0-40 feet.
		Columbia Group Terraces: Northport Terrace (2d) University Terrace (3d)	Sands, clays and gravels of second and third stream terraces. (Satilla and Okefinokee of Georgia), 50 to 60 and 100 to 150 feet above stream levels.
	Pliocene	Lafayette Group	Gravels, sands and clays resting on all formations from the crystalline and Paleozoic rocks to and including those of Pliocene age.
			Some of the sands, clays and gravels possibly represent deposits of early Pliocene age in southeast Alabama.
	Miocene		Beds present in Florida but not as far north as Alabama.
Tertiary	Oligocene		Alum Bluff formation, outcrops south of Alabama. Chattahoochee formation, outcrops south of Alabama.
	St. Stephens Group	Vicksburg or Marianna Limestone	White Orbitoidal Limestone Echinoids numerous, Orbitoides, Corals, *Pecten poulsoni.*
		Jackson or Ocala Limestone	Highly fossiliferous limestone with Bryozoa, *Pecten perplanus*, *Periarchus pileus-sinensis* and numerous other fossils. Thickness, 50 to 100 feet.
	Claiborne Group	Lisbon formation	Calcareous, glauconitic clays and white, sandy, glauconitic limestone and marl. Alternating hard and soft strata in marls. *Ostrea sellaeformis* ranges throughout. Thickness, 60 to 75 feet.
		Tallahatta formation (Buhrstone) (Slight unconformity)	Indurated and silicified clays or claystone, yellowish glauconitic sands with *Ostrea sellaeformis*. White sand with *Ostrea divaricata* at top. Thickness, 130 to 145 feet.

	Hatchetigbee formation	*costa* (large), *V. Silimani, Rostellaria trinodifera, Protocardia nicolleti, Pseudoliva vetusta, Cytherea Hatchetigbeensis*, etc., *Spondylus damosus, Plicatula filamentosa*. Thickness, 175 feet.
Eocene	Wilcox Group — Bashi formation (Wood's Bluff)	Sandy clays, sands and clays with several thin beds of lignite and fossiliferous green sand marl at top. *Protocardia nicolleti, Venericardia planicosta, etc., etc.* Thickness, 75 feet.
	Wilcox Group — Tuscahoma formation	Alternating beds of laminated clays, sandy laminated clays, and sands with highly fossiliferous green sand marl at top with large *Voluta Newcombiana*, large *Turritella Mortoni*, large *Venericardia planicosta*, etc. Thickness, 150 to 220? feet.
	Wilcox Group — Nanafalia formation (Coal Bluff lignite at base)	White quartz sand and clay, highly fossiliferous green sand with large boulders (fossils *Gryphaea thirsae, Ostrea compressirostra*) and kaolin-like clay with indurated fossiliferous ledges above. Thickness, 130? to 250 feet.
Upper Cretaceous	Midway Group — Naheola formation	Alternating beds of sandy laminated clays and cross-bedded sands with fossiliferous green sand marl at base. *Venericardia rotunda, V. Smithi, Rostellaria trinodifera, etc.* Thickness, 150 feet.
	Midway Group — Sucarnochee formation	Black clays and sands, clays calcareous to westward. Fossiliferous at base. *Nautilus, Dentalium, Peeten Alabamensis, Leda, Coral*, Crab remains. Thickness, 100 to 200 feet.
	Midway Group — Clayton formation	Limestone and calcareous sand. Nautilus rock upper and Turritella rock lower limestones. Fossils: *Enclimatoceras, T. humerosa, Venericardia planicosta*, etc. Thickness, 25 feet.
	Unconformity	
	Ripley	Glauconitic and blue clayey sands with frequent thin hard sandy calcareous ledges. Fossils: *Exogyra costata, Ostrea larva*, etc. 0 to 300 feet.
	Selma Chalk	Massive argillaceous limestone or chalk. Fossils: *Exogyra costata, E. ponderosa, Ostrea larva, O. plumosa, Inocerami, etc.* Thickness, 800 to 1,000 feet.
	Eutaw formation	Clays and sands of marine origin, calcareous at top. Fossiliferous. Thickness, 300 feet.
	Unconformity?	
Cretaceous	Tuscaloosa formation	Unconsolidated sands, usually cross-bedded and massive clays of continental origin. Leaf impressions. Thickness, 1000 feet.

Recent and Quaternary	Pleistocene		First Bottom		River flood plain sands, clays and gravels.
			Northport Terrace University Terrace		Sands, clays and gravels of second and third river terraces.
	Pliocene		Lafayette Group Citronelle formation		Gravels, sands and clays; reddish sand, clay and sandy clay, gravel toward inland margin. Sand rounded, gravel rounded to subangular quartz. 50 to 300 feet.
	Miocene		Pascagoula Clay		Bluish and gray clays, sand and sandy clay. 250 plus feet thick.
	Oligocene	Grand Gulf Group	Hattiesburg Clay		Bluish and gray clays, sands and sandstone. Non-massive. 200 plus feet thick.
			Catahoula formation		Unconsolidated sands, sandstone, greenish and blue clays. 200 plus feet thick.
		St. Stephens Group	Coral or Salt Mountain limestone		Hard white limestone composed largely of partly silicified coral. Exposed at Salt Mountain, Clarke County. Thickness, 150 feet.
			Vicksburg formation		Hard crystalline to soft white pulverulent limestone. Fossils *Orbitoides mantelli, Pecten poulsoni*, etc. About 140 feet thick.
			Jackson formation		Soft impure limestone with thin strata of harder limestone and thin beds of clay. Fossils *Pecten perplanus, Periarchus, pileus-sinesis, Spondylus dumosus, Ostrea cretacea, Zeugolodon cetoides, Amusium Ocalanium.* 60 to 1,200 feet thick.
rtiary		Claiborne Group	Gosport green sand		Yellow to reddish sandy marl with very abundant fossils as: *Venericardia, Cytherea aequorea, Lucina sps. Flabellum Wailesii? Ostrea Johnsoni*, etc. *Dentalium thalloides*, etc. *Rostellaria velata*, etc. Several hundred species in all. Thickness, 20-30 feet.
			Lisbon formation		Yellowish sandy marl with hard, more calcareous ledges. Great numbers of large *Ostrea sellaeformis*. Also other fossils in large numbers. Thickness, 100-120 feet.
			Tallahatta formation (Buhrstone)		White indurated siliceous claystone (greenish when wet) streaked with yellow bands of iron oxide; hard, [illegible]

AGE	SERIES
Recent	
Quaternary	Pleistocene
Tertiary	Pliocene
	Miocene
	Oligocene
	Eocene
Cretaceous	Upper Cretaceous or Gulf Series

FIG. 24.—CORRELATION TABLE.

EAST TEXAS	LOUISIANA AND ARKANSAS	MISSISSIPPI	ALABAMA	GEORGIA
n deposits, silts, sands l. 0 to 50 feet.	First Bottom deposits, sands, silts and gravel	First Bottom deposits, silts, sands and gravel	First Bottom deposits, silts, sands and gravel	First Bottom deposits, sands and gravel
ces lay	Port Hudson formations: River terraces	Port Hudson formation river terraces	Northport Terrace University Terrace	Columbia terraces Satilla formation Okefinokee formation
and Gravel or rmation or nation stocene)	Lafayette formation (Citronelle formation included) (Plio-Pleistocene)	Lafayette formation (Citronelle formation inc.) (Plio-Pleistocene)	Lafayette formation (Citronelle formation) (Plio-Pleistocene)	Lafayette formation Altamaha formation Charlton formation
Clay Clay)	Pascagoula clay	Pascagoula clay	Pascagoula clay	Marks Head marl Duplin marl
Clay andstone	Fleming clay Catahoula sandstone Vicksburg formation	Hattiesburg clay Catahoula sandstone Vicksburg group (Byram marl, Marianna limestone, Red Bluff)	Grand Gulf group: Hattiesburg clay Catahoula formation	Alum Bluff formation Chattahoochee formati Vicksburg limestone (Marianna limeston
mation	Jackson formation	Jackson group: Yazoo clay Moody Branch marl	Saint Stephens Limestone { Vicksburg group / Marianna and Red Bluff / Jackson limestone }	Jackson group: { Barnwell sand / Tivola limestone } Ocala limes
roup: rmation ntain formation lman formation y formation	Claiborne group: Cockfield formation St. Maurice formation	Claiborne group: Lisbon and Cockfield Tallahatta formation Basic claystone Winona sand	Claiborne group: Gosport Greensand Lisbon formation Tallahatta buhrstone	Claiborne group (undifferentiated)
nation	Wilcox formation (Sabine formation)	Wilcox group: Hatchetigbee or Grenada Bashi formation Holly Spring sand Ackerman clay	Wilcox group: Hatchetigbee formation Bashi formation Tuscahoma formation Nanafalia formation	Wilcox group (undifferentiated)
mation	Midway formation	Midway group: Tippah sandstone Porter Creek formation Clayton limestone	Midway group: Naheola formation Sucarnochee formation } Clayton limestone Clayton limestone	Midway formation Clayton limestone)
EAST TEXAS				
rma- Arkadelphia clay Nacatoch sand	Arkadelphia clay Nacatoch sand	Ripley formation / Selma chalk	Ripley formation / Selma chalk	Ripley formation Providence sand Cusseta sand
l Pecan Gap chalk Wolf City sand Taylor marl Marlbrook marl	Marlbrook marl Saratoga chalk Annona chalk Brownstown marl Blossom sand			
k Annona chalk Browstown marl Blossom sand				
for- Eagle Ford formation	Bingen formation Woodbine sand	Eutaw formation: Coffee sand Tombigbee sand	Eutaw formation Tombigbee sand	Eutaw formation Tombigbee sand
or- Woodbine formation		Tuscaloosa formation	Tuscaloosa formation Upper Cretaceous and Lower Cretaceous	Lower Cretaceous

E	SERIES	EAST TEXAS		LOUISIANA AND ARKANSAS	MISSISSIPPI	AL
		First Bottom deposits, silts, sands and gravel. Thickness, 0 to 50 feet.		First Bottom deposits, sands, silts and gravel	First Bottom deposits, silts, sands and gravel	First Botton sands and
ary	Pleistocene	River Terraces Beaumont Clay		Port Hudson formations: River terraces	Port Hudson formation river terraces	Northport T University T
	Pliocene	Lissie Sand and Gravel or Lafayette formation or Uvalde formation (Plio-Pleistocene)		Lafayette formation (Citronelle formation included) (Plio-Pleistocene)	Lafayette formation (Citronelle formation inc.) (Plio-Pleistocene)	Lafayette fo (Citronell (Plio-Plei
	Miocene	Pascagoula Clay (Fleming Clay)		Pascagoula clay	Pascagoula clay	Pascagoula
	Oligocene	Hattiesburg Clay Catahoula Sandstone		Fleming clay Catahoula sandstone Vicksburg formation	Hattiesburg clay Catahoula sandstone Vicksburg group (Byram marl, Marianna limestone, Red Bluff)	Grand Gulf Hattiesbu Catahoula f
	Eocene	Jackson formation		Jackson formation	Jackson group: Yazoo clay Moody Branch marl	Saint Stephens Limestone
y		Claiborne Group: Yegua formation Cook Mountain formation Mount Selman formation Queen City formation		Claiborne group: Cockfield formation St. Maurice formation	Claiborne group: Lisbon and Cockfield Tallahatta formation Basic claystone Winona sand	Claiborne g Gosport (Lisbon fo Tallahatt
		Wilcox formation		Wilcox formation (Sabine formation)	Wilcox group: Hatchetigbee or Grenada Bashi formation Holly Spring sand Ackerman clay	Wilcox gro Hatchetig Bashi for Tuscahor Nanafali
		Midway formation		Midway formation	Midway group: Tippah sandstone Porter Creek formation Clayton limestone	Midway gr Naheola format Sucarnoc format Clayton limesto
	Upper Cretaceous or Gulf Series	DALLAS	EAST TEXAS	Arkadelphia clay Nacatoch sand	Ripley formation	
		Navarro formation	Arkadelphia clay Nacatoch sand			
		Taylor marl	Pecan Gap chalk Wolf City sand Taylor marl	Marlbrook marl Saratoga chalk Annona chalk Brownstown marl Blossom sand	Selma chalk	Selma ch
ceous		Austin chalk	Marlbrook marl Annona chalk Browstown marl Blossom sand			
		Eagle Ford formation	Eagle Ford formation	Bingen formation Woodbine sand	Eutaw formation: Coffee sand Tombigbee sand	Eutaw for Tombigb
		Woodbine formation	Woodbine formation		Tuscaloosa formation	Tuscaloosa Upper (Lower (

GEORGIA

First Bottom deposits, silts, sands and gravel

Columbia terraces
Satilla formation
Okefinokee formation

Lafayette formation
Altamaha formation
Charlton formation

Marks Head marl
Duplin marl

Alum Bluff formation
Chattahoochee formation
Vicksburg limestone
(Marianna limestone)

Jackson group:
Barnwell sand
Tivola limestone
} Ocala limestone

Claiborne group
(undifferentiated)

Wilcox group
(undifferentiated)

Midway formation
Clayton limestone)

Ripley formation
Providence sand
Cusseta sand

Eutaw formation
Tombigbee sand

Lower Cretaceous

E	SERIES	EAST TEXAS	LOUISIANA AND ARKANSAS	MISSISSIPPI	ALA
		First Bottom deposits, silts, sands and gravel. Thickness, 0 to 50 feet.	First Bottom deposits, sands, silts and gravel	First Bottom deposits, silts, sands and gravel	First Bottom sands and
nary	Pleistocene	River Terraces Beaumont Clay	Port Hudson formations: River terraces	Port Hudson formation river terraces	Northport Te University T
	Pliocene	Lissie Sand and Gravel or Lafayette formation or Uvalde formation (Plio-Pleistocene)	Lafayette formation (Citronelle formation included) (Plio-Pleistocene)	Lafayette formation (Citronelle formation inc.) (Plio-Pleistocene)	Lafayette fo (Citronelle (Plio-Pleis
	Miocene	Pascagoula Clay (Fleming Clay)	Pascagoula clay	Pascagoula clay	Pascagoula c
	Oligocene	Hattiesburg Clay Catahoula Sandstone	Fleming clay Catahoula sandstone Vicksburg formation	Hattiesburg clay Catahoula sandstone Vicksburg group (Byram marl, Marianna limestone, Red Bluff)	Grand Gulf g Hattiesbur Catahoula fo
	Eocene	Jackson formation	Jackson formation	Jackson group: Yazoo clay Moody Branch marl	Saint Stephens Limestone
y		Claiborne Group: Yegua formation Cook Mountain formation Mount Selman formation Queen City formation	Claiborne group: Cockfield formation St. Maurice formation	Claiborne group: Lisbon and Cockfield Tallahatta formation Basic claystone Winona sand	Claiborne gr Gosport G Lisbon for Tallahatta
		Wilcox formation	Wilcox formation (Sabine formation)	Wilcox group: Hatchetigbee or Grenada Bashi formation Holly Spring sand Ackerman clay	Wilcox grou Hatchetigh Bashi forn Tuscahom Nanafalia
		Midway formation	Midway formation	Midway group: Tippah sandstone Porter Creek formation Clayton limestone	Midway gro Naheola formati Sucarnoch formati Clayton limeston
		DALLAS / EAST TEXAS			
	Upper Cretaceous or Gulf Series	Navarro formation / Arkadelphia clay, Nacatoch sand	Arkadelphia clay Nacatoch sand	Ripley formation	
eous		Taylor marl / Pecan Gap chalk, Wolf City sand, Taylor marl	Marlbrook marl Saratoga chalk Annona chalk Brownstown marl Blossom sand	Selma chalk	Selma cha
		Austin chalk / Marlbrook marl, Annona chalk, Browstown marl, Blossom sand			
		Eagle Ford formation / Eagle Ford formation	Bingen formation Woodbine sand	Eutaw formation: Coffee sand Tombigbee sand	Eutaw forn Tombigbe
		Woodbine formation / Woodbine formation		Tuscaloosa formation	Tuscaloosa Upper C a Lower C

	GEORGIA
ilts,	First Bottom deposits, silts, sands and gravel
	Columbia terraces Satilla formation Okefinokee formation
	Lafayette formation Altamaha formation Charlton formation
	Marks Head marl Duplin marl
	Alum Bluff formation Chattahoochee formation Vicksburg limestone (Marianna limestone)
and	Jackson group: Barnwell sand, Tivola limestone — Ocala limestone
	Claiborne group (undifferentiated)
n	Wilcox group (undifferentiated)
e	Midway formation Clayton limestone)
tion	Ripley formation Providence sand Cusseta sand
	Eutaw formation Tombigbee sand
	Lower Cretaceous

and afford excellent exposures of the supporting formations. The relief is as much as 250 or 300 feet.

Southern Limestone Hills.—This subdivision extends as a narrow strip across the State from the Mississippi line to the Chattahoochee River in the extreme southeastern part of the State. In the western portion of the belt the country is hilly while to the eastward the topography becomes more rolling to flat and is frequently covered with sands and clays of more recent age than the Jackson and Vicksburg formations which are the surface-making formations. In this section there are also numerous limesinks from which the name "Limesink Region" was derived and used in both Alabama and Georgia.

Rolling Piney Woods Country.—This subdivision composes all of that upland part of the State south of the limestone belt and is the area of outcrop of all of the formations from Grand Gulf to Pleistocene age. The topography is generally gently rolling to flat with sandy to sand-clay soils. The maximum elevation of the area is some 250 feet above sea level.

Mobile Delta.—This area is the lowland of the delta of the Mobile River south of the confluence of the Alabama and Tombigbee rivers.

Coast Strip.—The narrow sandy lowland strip and islands along the coast have been named the Coast Strip.

AREAL GEOLOGY.

Geological Sections.

The columnar section headed "Chattahoochee River Section" is compiled primarily from the section made by D. W. Langdon, formerly of the Alabama Geological Survey, and is representative of all strata with their thicknesses as seen by him on a tour down the Chattahoochee River. It is probable that the total thickness of the entire section is somewhat greater than is indicated by Langdon. However, this difference cannot be very considerable and this section is fairly representative of the character of materials of the formations which compose the Coastal Plain of Eastern Alabama together with their respective thicknesses. The section as given by Langdon is included in this report (Figure 22).

The Alabama and Tombigbee River sections (Figure 23) have been compiled from the work and publications of Dr. Eugene A. Smith, while the area has been recently studied and checked by the writer from the Tuscaloosa formation upward through the series to the base of the Vicksburg group. From the base of the Selma Chalk to the top of the Jackson a complete section of the strata was seen and noted almost foot by foot, which leaves little room for error in the character of the materials as given with the respective thicknesses of the various formations. A slight hiatus exists between the Nanafalia formation and the Tuscahoma formation which, however, cannot concern more than 20 to 25 feet of beds. The contact of these two formations was definitely seen in Marengo County but was covered along the Alabama River. This section is composite of the exposures along the Alabama and Tombigbee Rivers and the contiguous areas. Above the St. Stephens group the data as given, have been compiled from publications by various authors. The logs of wells drilled in this area have been used to check the thicknesses of the various formations and therefore we can be reasonably certain of the accuracy of the figures given.

On Figure 24 there is given a correlation table of the formations from the base of the Upper Cretaceous to the recent deposits, extending across the Gulf Coastal Plain from East Texas to the Atlantic seaboard in Georgia. No attempt has been made to make a minute correlation based on the paleontologic characteristics of the different formations but the table is presented primarily from the standpoint of the lithology without, however, neglecting the broader consideration of the fossil content of the various horizons. An attempt has been made to show broadly the upward-eastward transition of the Austin Chalk which occurs in the upper lower half of the Gulf Series in Texas, to the Selma Chalk of Alabama which occupies in part, that horizon from middle Austin to the top of the Upper Cretaceous.

CRETACEOUS SYSTEM.

The surface terrane of Cretaceous strata in the Gulf Coastal Plain beginning on the eastern border of Georgia extends in a southwesterly direction to the Chattahoochee River thence west and northwest across Alabama, north-

ward through the northeast corner of Mississippi, thence slightly east of north, through Tennessee and bending westward to the vicinity of Cairo, Ill. Underlying and outcropping immediately north of the Cretaceous Terrane from Central Alabama, northeastward through Georgia, are metamorphosed rocks of the pre-Cambrian Piedmont Area. Northwestward from Central Alabama Paleozoic beds immediately underly the Cretaceous.

This trend of Cretaceous outcrop defines in effect a great monoclinal nose caused jointly by the Appalachian Uplift and the Mississippi Embayment. This great nose was not formed by an pulift subsequent to the deposition of the Coastal Plain strata but rather by movements prior to this deposition causing shore lines which conformed to the present line of outcrop of the Cretaceous strata. Correctly speaking, this might not be termed a "nose" but since the dips conform in general direction to a true monoclinal nose the effect and appearance is the same and might be so considered. The axis of this regional structure has a direction parallel to or is the southwestward extension of the axis of the Appalachian Mountain system and the great anticlinorium of which the Birmingham Anticline is a member. The axial trend is about North 30° East-South 30° West.

Northward of the Coastal Plain area of Alabama, where strata of Cretaceous to recent age make up the land surface, rocks from Cambrian to Pennsylvanian-Pottsville age are exposed in the valley regions and coal areas while metamorphosed Archean to Cambrian sediments and later igneous rocks cover the surface of the Piedmont area of eastern Alabama. No deposits of materials of the periods between the Pottsville and Cretaceous seas occur within the State or in fact in the southeast with the exception of North Carolina and Virginia, where Triassic beds are present.

This absence of Jurassic, Triassic and Permian strata is indicative of the fact that during those periods of time the present Piedmont Plateau, Cumberland Plateau and the Palezoic areas of the southeast composed a land area which probably extended considerably further southwestward than the present limits of these areas. It is likewise probable that the southeasterr limit of the Piedmont area was much further southeastward than the present Fall Line or the

contact between the crystalline rocks and the Cretaceous sediments. This land mass possibly extended a considerable distance further eastward than the present land area of the southeastern United States.

In early Comanchic times there seems to have been a rapid transgression of the sea upon the land area reaching an inland limit somewhat north of the present Lower Cretaceous-Piedmont contact in Georgia and eastern Alabama and south of the Upper Cretaceous-Paleozoic contact in Middle and Northwestern Alabama. The northern limits of the Lower Cretaceous have not been defined in the two last mentioned areas because of its being overlapped by Upper Cretaceous strata and no wells having penetrated the Lower Cretaceous formations. The western limit of the Lower Cretaceous strata in Alabama, according to Berry,* is along the eastern line of Autauga County which is also approximately the western limit of the Pre-Cambrian area. This is suggestive of the possibility that the Lower Cretaceous shore line continued westward or southwestward around a southwest extension of the Paleozoic and Piedmont land mass. We would then expect to find Lower Cretaceous beds below the Upper Cretaceous somewhere south of the present landward margin of the Tuscaloosa formation. At the beginning of the Lower Cretaceous time the Cretaceous shore line changed very little along the Piedmont land area but transgressed for a considerable distance inland over the Paleozoics in Alabama and northward almost to the Ohio River.

The Tuscaloosa beds, the lowest member of the Upper Cretaceous series, are apparently resultant from deposition by rather numerous streams or one or more very large rivers having a rapid run off from the Paleozoic land area. These crossbedded and discontinuous sands and clays seem to have been dropped by the streams as the foot of the steep fall of the stream channels, probably in shallow fresh waters, as delta deposits or as a continental fan. A luxuriant floral growth in shallow and fresh water marginal swamps is indicated by the rather abundant plant remains in the Tuscaloosa clays in some localities. No marine fossils have been found.

*Berry, E. W. "Upper Cretaceous Floras of the Eastern Gulf Region in Tennessee, Mississippi, Alabama, and Georgia," U. S. G. S., Prof. Paper 112, 1919.

The Tuscaloosa interval ended with a sinking of the near shore sea floor and the inundation of the marginal swamps and lakes with a consequent transgression of the shore line, hardly further, or as far, inland as the present landward limit of the Tuscaloosa sediments. In this sea the marine Eutaw sands and clays were deposited. The cross-bedded and discontinuous nature of the Eutaw sands and clays indicate a rather perturbed sea, quite similar in effect to the conditions under which the Tuscaloosa beds were deposited, but in marine waters. In fact, it might be considered that the Tuscaloosa and Eutaw formations were deposited under very similar conditions of drainage and transportation with the Tuscaloosa in marginal fresh water bodies, and the Eutaw in shallow sea water that had transgressed inland covering the Tuscaloosa fresh water marshes. The Eutaw beds extend a hundred or more miles further eastward than the Tuscaloosa and here rest unconformably upon the Lower Cretaceous strata.

Toward the end of the Eutaw deposition there was a very marked change in the drainage conditions off the Paleozoic area. Where the major streams had originally paralleled the axis of the Appalachian Uplift, bringing the greatest quantity of land wash to the southwest end of the Paleozoic land area, they now were diverted northwestward and southeastward. The possibility presents itself that the Tennessee River, which had found an outlet to the sea through or near the present Warrior River channel, was, at the end of the Eutaw, diverted northwestward at Guntersville, emptying into the Mississippi Bay in the extreme northwest corner of Alabama. At the same time the principal drainage systems of the Piedmont area were the Chattahoochee River and other streams to the east. A slight landward transgression of the sea around the point of the Appalachian peninsular also took place about this time.

The result was that small streams carrying little burden emptied into a quiet, rather shallow sea extending from the Tennessee line in Mississippi southeastward and eastward through Mississippi and Alabama to near the Chattahoochee River. These streams drained limestone areas of the Paleozoic region and in consequence transported in solution comparatively large quantities of calcium carbonate, which, together with minute clay particles, was deposited largely through the medium of organisms as a massive im-

pure chalk bed reaching a maximum thickness of upward of 1,000 feet. This condition of deposition was continuous for some distance seaward since wells in Clarke County, Alabama and near Jackson, Mississippi, both 75 miles south to southwest of the seaward margin of the chalk outcrop, have penetrated the Selma, which shows a thickness of 950 feet in the first mentioned location, while wells penetrated about 500 feet and yet in the chalk near Jackson. The possibility of seaward transgression into chalk of the Eutaw sands and marls is eliminated by the uniform thickness of the Selma Chalk. A transgression would have resulted in an increased thickness seaward which is not shown by the available data except possibly in the Empire well on the Hatchetigbee Anticline.

The base of the Selma Chalk to the eastern limit in Russell County is a persistent horizon while eastward from Montgomery County to Russell County, the chalk decreases and the Ripley sands increase in thickness, occupying the upper horizon of the chalk zone and finally in Russell County and Georgia, including the entire horizon. Eastward of the chalk at the beginning of the Selma deposition the drainage channels had a rather rapid run off, bringing sands and clays in suspension and depositing them in a less quiet sea than the Selma waters. This condition of Riply deposition gradually became more effective with time, finally extending its character of sediments across the State to the Tombigbee River. Between the Tombigbee and Alabama Rivers the Ripley is both underlain and overlain by the Selma Chalk. The upper tongue of chalk is the medium forming the strip of black prairie soil extending eastward from Linden to near the Alabama River. Both Berry* and Stephenson have concluded that the Ripley finally merges into the Selma Chalk near the Tombigbee River and does not persist again as a distinct lithologic unit between the Tombigbee and Macon, Mississippi. Smith mapped the Ripley entirely across Alabama though he did not recognize it as a distinct lithologic unit west of the Tombigbee River.

The conclusion is that while the Selma and Ripley formations are distinct lithologic units, they occupy the same stratigraphic position and might logically be included as a "Group." In western Alabama the chalk occupies the en-

*Loc. cit. Prof. Paper 112, U. S. G. S.

tire horizon and in eastern Alabama the Ripley marls and sands made up the entire thickness. The Selma Chalk is the more persistent in the lower portion of the horizon, while the Ripley predominates in the upper part. The fossil zones are persistent through the horizon regardless of the character of the material. A more extensive original distribution northward of materials of the Ripley character in the Selma-Ripley horizon seems highly possible and on this basis of reasoning down the dip of the Selma-Ripley, particularly in middle Alabama where the sandy marls are comparatively thin, the Ripley may merge into the Selma Chalk, though it is not definitely shown by the records of wells drilled.

The foregoing study of the Cretaceous history is presented, not as a detailed and minute consideration of the controlling factors of Cretaceous times, but rather as a broad presentation of the possible major conditions of sedimentation to enable the reader to draw more readily conclusions as to the problems to be encountered in field studies in Alabama and their relation to the possibilities of the occurrence of petroleum. The presentation here given is based primarily upon the mechanics of the deposition of the various classes of sediments and the geography and topography of the affected areas without particular consideration of the paleontologic evidence.

The next few pages are devoted to a rather brief study of the principal characteristics of the Cretaceous formations, each taken separately.

UPPER CRETACEOUS.

The Cretaceous formations of Alabama outcrop as a belt ranging in width from somewhat more than fifty miles along the Chattahoochee River, the eastern boundary of the State, to a width of about one hundred thirty miles along the Mississippi line, the western boundary. The general direction of the belt is slightly north of west from the Chattahoochee River to Selma thence northwest to the Mississippi line. The Cretaceous is limited on the north and east by the Pre-Cambrian metamorphic or crystalline rocks and formations of the Paleozoic system from Cambrian to Carboniferous age, inclusive.

There are four distinct phases of the Cretaceous in Alabama that have each been given a formation name because of the characteristics of the different units and the conditions of deposition. Based on stratigraphic position and paleontologic evidence all of these formations are considered to be Upper Cretaceous age with the exception of the beds underlying the Eutaw formation in the eastern part of the State which have been determined to be of Lower Cretaceous or Comanchic age by E. W. Berry, who studied leaf impressions collected at Old Fort Decatur, Macon County, Alabama, by L. W. Stephenson.* The four subdivisions of the Cretaceous in Alabama in ascending order are as follows:

1. The *Tuscaloosa formation,* consisting of continental and marginal fresh water cross-bedded sands and vari-colored clays.
2. The *Eutaw formation,* composed of marine clays, sands, and glauconitic sands. The upper portion becomes calcareous. Fossils are frequent in certain horizons.
3. The *Selma Chalk* or *Rotton Limestone,* consisting of marine argillaceous limestone with more or less abundant faunal remains.
4. The *Ripley formation,* composed of sands, argillaceous sands, glauconitic sands and thin beds of hard calcareous sandstones or marl. Fossils are numerous in certain horizons.

The two species of Exogyra, *Exogyra costata* and *Exogyra ponderosa* are the most characteristic fossils of the Upper Cretaceous and on the basis of these the correlation of the Cretaceous of Alabama and Texas are made. In Alabama the lower limit of Exogyra costata is about the middle of the Selma-Ripley horizon or 500 feet below the top. This also marks the upper limit of *Exogyra ponderosa* which has its lower limit in the upper portion of the Eutaw formation. In Texas the lower limit of *Exogyra costata* and the upper limit of *Exogyra ponderosa* is about the top of the Taylor Marl or the base of the Navarro formation. The base of the *Exogyra ponderosa* zone is in the middle part of the Austin Chalk in the Austin-Dallas country. Therefore, from the fossil content as well as stratigraphic position the upper half of the Selma-Ripley formations of Alabama is

*Otto Veatch and L. W. Stephenson, Geology of the Costal Plain of Georgia, Bull. No. 26, Geological Survey of Georgia, 1911, page 77.

equivalent to the Navarro formation of Texas while the lower part of the Selma-Ripley is the time equivalent of the Taylor Marl and the upper half of the Austin Chalk. The Eutaw of Alabama is correlated with the lower half of the Austin and the Eagle Ford of Texas. The exact corresponding limits of these formations are not known. The Woodbine of Texas and the Tuscaloosa of Alabama are correlated together, each being the basal formations of the Upper Cretaceous or Gulf Series in their respective areas of outcrop, though the conditions of sedimentations were quite different.

TUSCALOOSA FORMATION.

This formation, including the Lower Cretaceous in Eastern Alabama, outcrops in a belt extending from Columbus, Georgia, on the Chattahoochee River, westward and northwestward to the Mississippi line, being the northernmost of the Coastal Plain formations. The width of the surface terrane varies from ten or twelve miles on the Chattahoochee River (Lower Cretaceous beds) to fifty or sixty miles in the northwestern part of the State. This area is characterized by a generally steeply rolling to hilly topography with frequent deep gullies which together have occasioned the name, "Fall Line Hills" in the southeast. The maximum relief is near three hundred feet with the high points along the Fall Line ranging from 500 to 600 feet above sea level.

The materials of the Tuscaloosa formation consist of vari-colored, massive and semi-laminated clays and sandy clays, cross-bedded and massive sands and small pockets or lenses of gravel. In the lower portion of the formation clays predominate while the sands are more abundant in the upper part. The pebble or gravel pockets are scattered practically throughout the formation but make up an inconsiderable proportion of the whole. Along the northern edge of the terrane where the Lafayette gravels lie directly upon the Tuscaloosa, it is frequently difficult to distinguish between the two. In general the Tuscaloosa gravels are less rounded than the Lafayette while again the Lafayette seems to be the reworked materials of the Tuscaloosa formation.

Some of the clay beds contain abundant plant remains while thin strata of lignitic material interbedded with the clays are not infrequent. The absence of marine fossils,

together with the nature of the materials exposed indicate or show that the beds are of continental or marginal fresh water and delta origin.

The Tuscaloosa materials weather into red clay, sand-clay and sandy soils.

There are no definite means of accurately computing the thickness of the Tuscaloosa beds since no wells have entirely penetrated the strata, and correlations from one well to another are impracticable because of the rapid gradation from one material to another and the absence of fossils. Hence it becomes necessary to make the determinations on the basis of the rate of dip per mile, which is only approximate, and the width of the outcrops. The normal rate of dip of the Tuscaloosa formation is estimated to be from 35 to 40 feet per mile. Along the Chattahoochee River where the Lower Cretaceous outcrop has a width of ten to twelve miles we would then have an approximate thickness of 400 feet which obtains westward to Wetumpka, the western limit of the Comanchean. In the Maplesville section the strata are near 750 feet thick, which increases to between 900 and 1,000 feet south of Tuscaloosa and on the Mississippi line.

The section given below is typical of the lower portion of the Tuscaloosa formation.

**Section above Saunders' Ferry, Black Warrior River, 8 miles southwest of Tuscaloosa.*

6. Rather massive clays of greenish and purple colors, breaking with conchoidal fracture. On drying these clays become hard and rock-like, resembling then, except in color, some of the claystones of the Buhrstone formation. These clays when wet soften and slide down the slopes, covering them completely in places. In this clay we find many rounded masses of ferruginous and siliceous matter of oolitic structure. Thickness of the clays ..... 40 feet
5. Laminated, sandy clays, gray, with partings, lignitic ..... 5 feet
   This bed is rather more coherent than the underlying and forms a slightly projecting or overhanging ledge.
4. Gray, cross-bedded sands, with partings of clay along many of the planes of false bedding, lignitic, leaf impressions ..... 25 feet
3. Slope or bench forty to fifty feet wide, covered by red clay and sands, slidden down from No. 1 and washed out of Nos. 2 and 3 ..... 3 feet
2. Gray or whitish, cross-bedded sands, forming the immediate bank of the river ..... 15 feet
1. Blue, micaceous sands to water level ..... 5 feet

*Smith, Eugene A., "Geology of the Costal Plain of Alabama," Geological Survey of Alabama, 1894, page 316.

EUTAW FORMATION.

The surface terrane of the Eutaw formation is a continuous belt from 8 to 10 miles in width, lying immediately south of the Tuscaloosa and Lower Cretaceous outcrops, and extending westward from the Chattahoochee River to the Selma meridian, thence northwestward to the Mississippi line east of Columbus, Mississippi. The most characteristic materials of the formation are bluish laminated clays and bluish to greenish laminated sands with occasional calcareous, fossiliferous beds and greensand marl. These sand and clay beds are very unusual in the manner in which they grade rapidly from one to the other or break off on almost a sharp line, the same horizon continuing as sand or clay as the case might be. This prenomenon is well exhibited in practically any exposure of considerable length and in the logs of wells drilled within a short distance of each other.

The upper 25 to 30 feet of the formation consist of calcareous sands and glauconitic marls, generally fossiliferous. Eastward of the eastern limit of the Selma Chalk the upper beds of the Eutaw formation become less calcareous. These calcareous beds evidently mark the change in conditions of sedimentation between the Eutaw and Selma.

Next below the calcareous beds are some 150 to 200 feet of sands and argillaceous sands which have been called the Tombigbee Sand member. Next below are some 200 feet of strata with laminated clays predominating. Eastward towards the Chattahoochee this lower portion becomes more sandy.

The Eutaw formation is evidently of marine origin containing more or less frequent fossiliferous beds, the principal fossils of which are *Ostrea Cretacea* Morton, *Ostrea plumosa* Morton, *Exogyra cancellata* Stephenson, *Exogyra ponderosa* Roemer, *Gryphaea aucella* Roemer, *Inoceramus, Cardium sps., Corbula crassiplica* Grabb, etc., etc. Lignitic material, leaf impressions and lignitized wood are frequently found in the laminated clays and sandy clays.

The Eutaw materials form sandy soils along the southern part of the outcrop and yellow to reddish sandy clay soils in the northern portion.

The thickness of the Eutaw has been variously estimated at from 250 to 600 feet. There are no positive data available from which to compute the thickness with any consid-

erable degree of accuracy, hence it is necessary to estimate a rate of dip per mile and calculate the thickness from the width of the surface terrane. Along the Selma meridian the width is approximately ten miles, which considering the dip, 30 to 35 feet per mile, would indicate a thickness of near 300 feet. In a water well at Selma the thickness seems to be somewhat less than this. Eastward toward the Chattahoochee River the Eutaw increases to a possible maximum of 500 feet while near the Mississippi line the thickness is probably near 400 feet.

SELMA CHALK.

The Selma Chalk outcrops in a belt from 20 to 30 miles wide, extending from the western edge of Russell County, westward to Selma, thence northwestward to the Mississippi line and lying immediately south of the surface terrane of the Eutaw formation. The material composing the Selma is primarily massive white argillaceous limestone and chalk of shallow water origin. Blue calcareous clays are also present in small thicknesses. The chalk is of a bluish color when wet and white to cream colored on dry oxidized exposures. Excellent exposures of the formation may be seen along any of the streams traversing its outcrop, along road cuts and in eroded spots in cultivated fields and prairies.

The soil derivative of the Selma Chalk is a yellow clay normally, but is usually black due to the presence of humus. These soils resemble very closely the soils of the Austin and Annona chalks and Taylor Marl of Texas but are not, as a whole, black to as great depth because of lesser quantities of humus. The topography is normally the gently rolling prairie type.

The maximum thickness of the chalk, based on an average dip of 30 feet per mile, is somewhat more than 1,000 feet. This maximum is probably reached in the area between the Alabama River and the Mississippi state line. Eastward from the Alabama River the chalk gets gradually thinner and disappears entirely near the western edge of Russell County. Westward from the Tombigbee the thickness as shown by an artesian well at Livingston, is 930 feet. A thickness of somewhat less than 900 feet is indicated by the record of a well near Myrtlewood, Marengo County. At

Camden, Wilcox County the chalk is somewhat more than 900 feet. At Union Springs the thickness is 515 feet. Eastward from this point the chalk thins rapidly until it disappears by merging along the strike into the Ripley marls.

The Selma Chalk is fossiliferous throughout, the principal family being the oyster, the most abundant of which are *Ostrea larva, Ostrea plumosa, Exogyra costata* (in the upper part) and *Gryphaea vesicularis*. Inoceramus and many other genera are likewise present. The faunal life is similar to but somewhat more abundant than that of the underlying Eutaw while the overlying and contemporaneous Ripley formation has the same fossils as the Selma.

RIPLEY FORMATION.

The Ripley formation or Ripley marl lies stratigraphically above the Selma Chalk throughout the extent of this formation in Alabama east of the Tombigbee River. Eastward of the east limit of the Selma Chalk, the lower portion of the Ripley is the time equivalent of the chalk, occupying the same stratigraphic position, so that in reality the Selma Chalk might be considered a phase of the Ripley formation. The difference in the conditions of sedimentation are discussed in another part of this paper.

Westward from the meridian of Troy the formation consists of blue micaceous argillaceous sands, blue clays, glauconitic marls, and thin ledges of calcareous sandstone. Thick hard ledges of highly fossiliferous sandy marl are also present, a notable exposure being on the Jackson Highway, one-half mile southwest of Gastonburg, Dallas County. Excellent exposures of the Ripley occur in bluffs of the Alabama River north of Camden, Wilcox County and in the neighboring hills and on the Tombigbee River near Moscow, Sumter County.

Section of Ripley Formation, Alabama River.

Tertiary, Clayton Formation:
9. Hard yellowish crystalline limestone with abundant *Turritella mortoni* (Turritella rock) ..... 8 feet

Cretaceous, Ripley formation:
8. Bluish micaceous argillaceous sand with fossils ..... 35 feet
7. Bluish sandy clay ..... 10 feet
6. Bluish sands, coarse grained ..... 10 feet
5. Bluish massive argillaceous micaceous sands with frequent hard ledges of calcareous sandstone, from 2 inches to 2 feet in thickness ..... 100 feet

4. Calcareous sandy clays of bluish color with shell casts in lower portion ..... 25 feet
3. Bluish sandy clay and calcareous blue sands and sandy argillaceous highly fossiliferous limestone ..... 30 feet
   The limestone thickens westward from Canton Landing (northwest of Camden) to at least 45 feet at Moscow Landing on the Tombigbee River.
2. Bluish fossiliferous sands containing thin ledges of hard highly fossiliferous calcareous sand. *Exogyra costata*, *Gryphaea vesicularis*. *Ostrea falcata* in sands ..... 25-30 feet

Selma Chalk:
1. Selma Chalk
   Total thickness of Ripley marl ..... 270 feet

The foregoing section, while approximately correct in general, does not attempt the detail of all the exposures studied. It is also possible that the total thickness given is somewhat less than the actual.

The blue sands and clays of the Ripley weather or oxidize into yellowish subsoils and generally black topsoils. The topography varies from very rough near the Alabama River, to more gently rolling and prairie-like away from the stream.

The most characteristic fossils are: *Ostrea falcata, Ostrea larva, Exogyra costata, Gryphaea vesicularis, Pecten quinquecostatus*, etc., etc.

At Troy, on the southern edge of the Ripley marl terrane, the formation has a thickness of nearly 450 feet, while at Union Springs the thickness of the Selma Chalk is 515 feet, giving a total of 965 feet for the two phases of the Ripley period sediments. Eastward of Troy and Union Springs, the Ripley increases in thickness, while the chalk decreases correspondingly until in Russell County and along the Chattahoochee River the chalk has disappeared entirely and the marl is about 950 feet in verical section. In character the materials along the Chattahoochee River resemble very closely those of the same formation along the Alabama River, but with fewer indurated sandy ledges so characteristic of the formation in the Bridgeport vicinity.

At the base of the Ripley on the Chattahoochee River there is a bed of calcareous sandy clay, having a thickness of about 125 feet. The remaining beds are gray to blue calcareous sands, yellowish cross-bedded sands, greenish glauconitic marls and a few indurated calcareous sand ledges. The strata are frequently fossiliferous. For a com-

plete section along the Chattahoochee River, see section by Langdon (Figure 22).

The fossil content is quite similar to or identical with that of the combined Selma and Ripley in the western part of the strata, namely, *Exogyra costata,* (upper half on Chattahoochee River) *Exogyra ponderosa* (lower portion), *Gryphaea vesicularis, Ostrea larva, Plicatula urticosa,* Anomia sp., etc., etc.

The Ripley soils of the eastern part of the State are generally yellowish sandy with narrow strips of tough yellow prairie land derivative of calcareous clays of the formation. These clays resemble very closely the subsoil of the Selma Chalk. The topography of the Ripley is generally hilly near the drainage channels to rolling and flat away from the main streams. Where there are local developments of indurated ledges a rough country is resultant.

TERTIARY SYSTEM.

EOCENE.

Formations of Eocene age outcrop across the southern portion of Alabama in a belt some sixty miles wide on the Mississippi line and forty miles in width along the Chattahoochee River. The general direction of the belt is about North 15° West-South 15° East. The entire thickness of the series is nearly 1,000 feet in eastern Alabama and 1,600 to 1,800 feet in the Alabama River section and westward into Mississippi. Calcareous strata predominate at the base, cross-bedded and massive sands and laminated clays in the middle two-thirds, and calcareous strata in the upper one-fourth. The series has been divided into four groups and ten formations by E. A. Smith and others, each of which is distinctive in lithological character and to a lesser degree in fossil content. The materials are of both shallow marine and non-marine origin and show rather slight differences of conditions of sedimentation and a rather remarkable persistency in major characteristics from one side of the State to the other, considering the comparative thinness of the subdivisions. Excellent exposures of the strata are visible in the bluffs and the banks of the three major streams which traverse the outcrop of the series, namely: the Chattahoochee, Alabama, and Tombigbee Rivers. These river exposures together with outcrops along the tributaries in the

immediate vicinity of the major streams, enable descriptions of the various beds of the formation almost foot by foot. These sections can be checked against various well logs to the point that one can feel reasonably certain of the accuracy of the resultant sections.

The reader is referred to the sections on Figures 22 and 23 for the broader characteristics while the formations are described in more or less detail on the next succeeding pages.

MIDWAY GROUP.

In the western and middle parts of Alabama the Midway Group has been subdivided into three formations: the Clayton limestone at the base and the Sucarnochee and Naheola formations above. The Ripley beds below the Midway are near shore deposits of argillaceous, calcareous sands while the Clayton limestone was deposited in somewhat deeper quiet waters. A slightly wavy line of contact with phosphatic nodules shows an unconformable relationship between the Cretaceous and Tertiary beds. In the eastern part of the State this unconformity is marked by a bed of very coarse-grained or conglomeratic sandstone. The data at hand are insufficient to determine the extent of the unconformity though it is evident that the time interval between the Cretaceous and Tertiary seas over the present area of contact was slight.

The type locality of the Midway is at Old Midway Landing, Wilcox County on the Alabama River where the Clayton limestone is exposed. The name "Midway" is rather unfortunate since the beds occur at the base of both the Tertiary system and the Eocene Series, which makes the name rather misleading, even though having been named for a locality and not intended to denote the stratigraphic position. Smith at one time proposed that the name be changed to Clayton since near the town of that name the lower limestones are well developed. It seems that this would be a very satisfactory designation.

CLAYTON LIMESTONE.

The thickness of the Clayton Formation or Clayton Limestone in the Alabama River area is about 25 feet with five to ten feet of dark yellow to brownish-semi-crystalline limestone at the base containing abundant *Turritella Mor-*

toni and Turritella humerosa from which the name *"Turritella* Rock" was derived. *Venericardia planicosta,* oyster shells and coral are likewise present. This bed is overlain by about 5 feet of calcareous sand which is in turn overlain by ten feet of limestone containing *Enclimatoceras Ulrichi,* White, from which the name "Nautilus Rock" was given to the limestone by Smith. The Turritella Rock is exposed as large boulders 3½ miles southwest of Minter on the Camden road, and the Nautilus Rock at the base of Grave Yard Hill, near Allenton, in Section 5, Township 11, Range 10 E., where the section has been described by E. A. Smith as follows:

Section from top of Grave Yard Hill to Pine Barren Creek.

Sucarnochee Formation .

8. Grayish white, calcareous sand, with small phosphatic nodules, characterized by an abundance of crustacean remains ..... 5 feet
7. Whitish, calcareous sands, with several ledges which shale off in weathering ..... 20 feet
6. Hard, yellowish, sandy limestone, containing small phosphatic nodules. This is the rock which forms the walls around all the low hills in the vicinity ..... 2 to 3 feet
5. Yellowish, calcareous, clay sand, with white lime concretions, becoming grayer in color and more clayey, and containing numerous fossils identical with those found at Black Bluff ..... 15 feet
4. Black, calcareous clays, yellowish gray on weathered surfaces, also containing the Black Bluff fossils, but less abundantly than the preceding bed ..... 20 feet or more

Clayton Formation.

3. Hard grayish white limestone, characterized by great numbers of a large Nautilus (Enclimatoceras Ulrichi) and hence known as the Nautilus Rock ..... About 10 feet
2. Calcareous sands forming basis of the black, sandy prairies of this vicinity ..... 6 feet
1. Hard, yellowish white, crystalline lime rock, sandy in places and filled with red specks, highly fossiliferous, containing Turritella in great numbers; also Carditas, a Rostellaria, Ostrea, and two or three species of coral. This is one of the most persistent of the Tertiary rocks towards the east (Base of Tertiary) ..... 8 feet

West of the Alabama River, the Clayton limestone has been traced as far as the Tombigbee River. Eastward of the Alabama River the Clayton limestone increases in thickness, reaching a maximum of 200 feet on the Chattahoochee River below which there is an 18-foot bed of sandstone and conglomerate that is likewise referable to the Clayton Formation and marks the unconformable contact with the underlying Cretaceous.

Langdon (Figure 22 and page 5) measured 200 feet of soft white calcareous sand and argillaceous limestone along the Chattahoochee. A well-defined unconformity between the Clayton limestone and the overlying Wilcox strata is well displayed in the river bluff at Fort Gaines, Georgia, and at Brown's Mill on Cemochechobee Creek, one and one-half miles north of Fort Gaines. At this exposure there are frequent "pot holes" in the limestone ten to fifteen feet deep, filled with Wilcox materials. Eastward from this exposure the limestone is a hard pinkish variety with rather abundant fossils. Some of the Clayton fossils in eastern Alabama and western Georgia are *Ostrea pulaskensis, Ostrea crenulimarginata, Turritella mortoni* and *T. humerosa.*

SUCARNOCHEE FORMATION.

The Sucarnochee formation was named by Smith for Sucarnochee Creek in Sumter County where the beds are well exposed. At Black Bluff on the Tombigbee River he has described the following section:

3. Yellowish clay, which makes the basis of the Flatwoods, occupying top of bluff.....about 20 to 25 feet
2. Black, slaty clay, fossiliferous.....40 feet
1. Brownish shale or clay to water level.....8 to 10 feet

The total thickness of the black clays of the Sucarnochee make up the lower 30 feet of the formation while the remaining 70 to 80 feet are composed of calcareous sands and clays, shales and sandy limestones. The section on page 145 describes the lower 65 feet of the formation while 25 feet of sandy limestone, shale and glauconitic calcareous sands complete the section as described near Oak Hill.

No exposures of the Sucarnochee were recognized along the Alabama but from the general dip of the Clayton and Naheola beds and the interval between these formations, the Sucarnochee has a thickness of from 110 to 120 feet. It is the basis of the Postoak Flatwoods described under "Topography."

The formation disappears or merges into the Clayton limestone between the Alabama and the Chattahoochee Rivers, probably in Butler or Crenshaw Counties.

NAHEOLA FORMATION.

Next overlying the Sucarnochee clays are some 150 feet of fossiliferous marls and alternating 10 to 20-foot beds

of sandy laminated clays and cross-bedded sands. At Matthews Landing on the Alabama River the Marl is exposed as follows:

3. Bluish to micaceous sandy marl with abundant fossils	5 feet
2. Dark grayish micaceous sandy marl with same fossils as bed 3 but less abundant and huge round concretionary boulders	4 feet
1. Black micaceous sandy marl with fewer fossils than either beds 2 or 3. Gastropods predominate	7 feet

A fault with a displacement of four feet was seen near the lower end of the bluff. The strata dip not more than 20 to 25 feet per mile southward. For about one mile below the bluff slight undulations in the strata are evident from the positions of the marl bed.

From Clifton Ferry downstream to Coal Bluff there are almost continuous exposures of alternating 10 to 20-foot beds of greennish laminated clay, laminated sands and cross-bedded sand. The laminated sand strata contain frequent large rounded concretionary calcareous sandstone boulders, similar to those at Matthews Landing but without fossils. These clay and sand beds are occasionally discontinuous or merge rapidly from one to the other. Slight undulations are evident in a number of places while at Clifton Ferry three faults with very little displacement were seen.

Some of the most characteristic Naheola fossils are as follows: *Voluta showalteri, Rostellaria velata* (very abundant), *Venericardia rotunda, Venericardia sillimani, Turritella mortoni, Turritella alabamensis, Leda eborea, Pseudoliva* sps,, *Natica,* sps., etc., etc.

The Tombigbee River exposures are quite similar to those on the Alabama with the same characteristic fossil and lithologic features. Eastward from the Alabama River the Naheola disappears as does the Sucarnochee.

In wells drilled for water and oil in the south-central and southwestern parts of the State, clay and shale strata were encountered in the entire stratigraphic position of the Midway. No differentiation of the three formations can be made from the logs, because of the similarity of the strata as reported. This seaward transition from near shore sands and clays to more coherent deeper water clays and shale is the natural resultant of a normal condition of deposition. The shales and "gumbos" are reported in the logs to be gray to blackish. See log of Mitchell No. 1, page 204.

WILCOX GROUP.

The next series of beds, stratigraphically above the Midway, has been named the Wilcox Group from the typical exposures of the strata in Wilcox County along the Alabama River. This group and formation name have been extended to include all of the strata of the Alabama Wilcox horizon from Georgia into Texas.

In Eastern Alabama the conditions of sedimentation in Midway and Wilcox times were somewhat different, the former are primarily limestones and calcareous sands, while the latter, Wilcox, are near shore marine and fresh water laminated clays and sands and cross-bedded sands. The lithologic and paleontologic characteristics of the Wilcox obtains across the entire State while the thickness diminishes to the eastward. The group has been subdivided by Smith into four formations: the Nanafalia, at the base; and the Tuscahoma, Bashi and Hatchetigbee formations upward in the order named. Each of these formations has very distinctive characteristics which are described briefly on succeeding pages. A more or less complete succession of the beds along both the Chattahoochee and Alabama Rivers is given in Figures 22 and 23, while the vertical section in Clarke County is shown in the record of the Bollinger No. 1 well. An unconformity is evident between the Midway and Wilcox beds in Eastern Alabama and quite probable in the western part of the State though not definitely recognized.

NANAFALIA FORMATION.

The Nanafalia formation, the lower-most of the Wilcox Group, consists of from 125 to 150 feet in ascending order of lignite, massive and laminated sands and clays, cross-bedded sands, highly fossiliferous greesand marl and kaolin-like laminated to thick-bedded clays, with thin, highly fossiliferous indurated beds. The formation is readily subdivided into three lesser divisions based on both lithology and fossil content. In order to assist in the description of certain features concerning the formation, the lower of the three phases will be referred to as the Coal Bluff beds while the two upper phases will be referred to as the Gullette Bluff beds, where their entire thickness is well exposed. Smith has used the term "Coal Bluff" to apply to the lignite

at the base of Nanafalia. In this paper the name is extended to include all the strata below the Gullette Bluff fossiliferous marl.

The Coal Bluff beds consist of 2 to 7 feet of lignite at the base overlain by 40 to 70 feet of cross-bedded sands, laminated clays and sandy clays with sand lenses and at the top a 20-foot bed of yellow to clean white cross-bedded sands with a few tough blue clay streaks and lenses or flattened pebbles. The best development of these beds is in Wilcox County. Westward in Marengo they have a 60-foot thickness while on the Chattahoochee River according to Langdon's Section they are entirely absent.

The following section is descriptive of the Gullette Bluff and Coal Bluff in Wilcox County:

Composite Section of Nanafalia Formation in Wilcox County. Black's Bluff, Alabama River.

27. Lafayette sands and gravel ..... 25 feet
26. Blue laminated, jointed clay weathering to tough yellow clay ..... 42 feet
25. Hard calcareous fossiliferous sandy claystone with fossils ..... 2 feet
24. Blue, laminated to jointed clay, cream colored on dry exposure ..... 6 feet
23. Sandy fossiliferous calcareous claystone ..... 5 feet
22. Blue kaolin-like clay, conchoidal fracture ..... 25 feet
21. Hard, glauconitic calcareous claystone with fossils ..... 3 feet
20. Blue joint clay with a few sandy layers ..... 6 feet
19. As bed 21 ..... 2 feet
18. As bed 22 ..... 10 feet
17. Hard sandy bed with high percentage of glauconitic oxidizing to limonite ..... 6 feet
16. Unconsolidated white to yellow sand (seen only at Black Bluff) ..... 5 feet
15. Laminated sand and clay ..... 9 feet

Grampian Hills, 2 miles southeast of Camden.

14. Hard highly fossiliferous glauconitic clay. Upper limit of *Gryphaea thirsae* ..... 2 feet
13. Glauconitic sandy marl with large numbers of *Gryphaea thirsae* ..... 8 feet
12. Laminated sandy clay, blue ..... 5 feet
11. Glauconitic *Gryphaea thirsae* marl ..... 30 feet
10. Glauconitic sand, no fossils ..... 3 feet
9. White to yellow cross-bedded massive sands with blue clay lenses ..... 20 feet

Section above Gullette Bluff on Gravel Creek and Alabama River.

8. Black laminated carbonaceous clay ..... 5 feet
7. Unconsolidated sand with boulders ..... 8 feet
6. Black laminated clay ..... 8 feet

5. Unconsolidated sand and boulders, glauconitic	8 feet
4. Black laminated clays	10 feet
3. Sand with boulders and hard ledges	15 feet
2. Lignite	4 feet
1. Lignitic shale	2½ feet
Total thickness of Nanafalia	250 feet

Beds one to nine of the above section are exposed in a series of bluffs along the Alabama River from Coal Bluff to Gullette Bluff and on Gravel Creek near the crossing of the Camden-Nellie road. The section can not be measured as closely as desired but the data as recorded are probably a very close approximation to the actual condition. The strata of beds 10 to 26, inclusive, are excellently exposed in a number of localities and very close measurements can be readily made. The exposure selected for the stratigraphic succession given in the section is in the Grampian Hills, two miles southeast of Camden, on the Camden-Fatama road. Quite a number of vertical-faced gullies display perfect sections of the sand bed below the marl and the lower twenty or thirty feet of the marl. The next succeeding strata are well exposed in a road cut on the northern scarp of the Grampian Hills on the Fatama road. The exposure of the upper clays of the Nanafalia formation selected for the section is in the old road down Black's Bluff to the landing on the Alabama River, one mile below Gullette Bluff. The Gullette Bluff beds here have a thickness of 170 feet, while the exposed thickness at Gullette Bluff is 168 feet, and along the Camden-Nellie road up the hill south of Gravel Creek the thickness is about 175 feet. In each case Lafayette sand and gravel overlie the clay so it is possible that the maximum thickness is somewhat more than that exposed.

The Nanafalia section as exposed in Marengo County on the Linden-Nanafalia road shows the formation to be somewhat thinner than on the Alabama River. The following section was observed on Geneva Hill one-fourth mile south of Nolan's store, Section 23, Township 14, Range 1 East.

Geneva Hill Section, Marengo County.

7. Massive greenish sand with glauconitic, clear, quartz sand, and blacksand; lies unconformably on next bed below	20 feet
6. White, massive, to cross-bedded white and yellow sands, black sand streaks	15 feet
5. Laminated to jointed bluish clay (weathers cream colored) with two 18-inch beds of hard, sandy fossiliferous clay-	

stone. Fossils: *Turritella mortoni* (large), *Venericardia planicosta*, *Gryphaea thirsae* (comparatively few) ..... 30 feet
4. Greensand marl with *Gryphaea thirsae* in large numbers ..... 20 feet
3. Clayey glauconitic sand similar to marl but without fossils; large round concretionary boulders at the base ..... 6 feet
2. Gray laminated clay with some sand and glauconite ..... 4 feet
1. White cross-bedded sand, grading into yellow at base; gray clay pebbles and lenses frequent ..... 20 feet

Lignite outcrops about 65 feet below base of bed No. 2. With Naheola clayey sands exposed in creek bank 85 feet below.

From the above the Coal Bluff Beds have an apparent thickness of about 70 feet while the overlying Gullette Bluff beds have a thickness of about 60 feet (beds 2 to 5, inclusive). Overlying the Nanafalia is a 15-foot bed of sand which is apparently the lowest member of the Tuscahoma formation. Three miles south of this exposure the sand has a thickness of 35 feet with the 20 feet of greenish sand above. There are no fossils in the two beds overlying the Nanafalia clays but from the lithologic character of the material of these and the strata succeeding above, they are referable to the Tuscahoma formation. This section shows the Nanafalia to have a total thickness of about 130 feet which is very close to the exact thickness, though the Coal Bluff beds were not seen in complete section. Where exposures were visible the character of the materials seems to be the characteristic laminated and carbonaceous clays and cross-bedded glauconitic sands. Smith described several exposures on the Tombigbee River of characteristic Nanafalia beds with a hiatus of 16 feet at the top and an eighteen foot hiatus in the *Gryphaea thirsae* greensand marl proper. He estimates the total thickness of the Nanafalia to be 200 feet with 100 feet of strata exposed above the base of the marl bed. A considerable thinning of the Nanafalia between the Alabama and Tombigbee rivers is evidenced by the section obtained along the Rembert-Nanafalia road.

Along the Chattahoochee River Langdon describes a section of 175 feet of Nanafalia marls, lithologically and paleontologically similar to the marls and overlying clays in the Alabama River section. The Coal Bluff beds seem to be missing in East Alabama. The succession of strata is shown in Langdon's Section (Figure 22) and pages 216 to 220.

The Nanafalia formation is well exposed on steep north-facing scarps, across Marengo and Wilcox Counties, which frequently attain an elevation of 200 feet above the drainage levels. The supporting mediums of these ridges are the

indurated beds in the upper portion of the formation. The gentle dip slopes to the southward together with steep north slopes, form cuestas in their general aspect. Two of the typical Nanafalia cuestas compose the Grampian Hills in Wilcox County and the hills to the south of Beaver Creek in Marengo County.

The characteristic fossils of the Nanafalia are *Gryphaea thirsae* in great abundance and *Ostrea compressirostra* in the glauconitic marls, and a few *Gryphaea thirsae,* abundant *Turritella mortoni* and *Venericardia planicosta* in the indurated beds in the upper clays and sandy clays. The Coal Bluff beds at the base contain no fossils. These very definite characteristics, both lithologic and paleontologic, of the Nanafalia formation, make it an excellent key horizon for structural and stratigraphic determinations in the Eocene formations across the entire State. Eastward of Butler County to the Chattahoochee River the typical greensand marls disappear, being replaced by the clays, sandy clays and siliceous claystones similar to the upper part of the West Alabama sections.

TUSCAHOMA FORMATION.

Next above the Nanafalia Formation is the Tuscahoma or Bell's Landing Formation, which consists of 150 to 200 feet of sands, sandy clays, laminated clays and fossiliferous greensand marls. Eastward from Wilcox County this formation gives rise to a rather flat monotonous country with few exposures of unweathered beds except along the major streams. Low bluffs on the Pea River near Elba exhibit rather poor exposures of unfossiliferous sandy clays, while Langdon considered 145 feet of gray sandy clays, interstratified with red sands and gray laminated sandy clays, exposed in bluffs along Choctawhatchie River near the Abbeville-Clayton road, 6 miles from Abbeville, Henry County, probably referable to the Tuscahoma. On the Chattahoochee River, beginning four miles south of Fort Gaines, Georgia, and continuing ten miles down stream, Langdon measured 170 feet of "Light yellow and gray sandy clays with round boulders in the sandier portion" which he correlates with the Bell's Landing and Lower Peach Tree exposures of the Tuscahoma.

At Yellow Bluff and Lower Peach Tree on the Alabama River the following section was obtained:

Composite section of exposures along Alabama River from Bell's Landing to a point 2 miles above Yellow Bluff.

Hatchetigbee Formation:
14. Yellow sandy laminated clays with thin layers of kaolin-like clay and thin sand strata. Dark yellow streaks cross the strata evidently from oxidized glauconite. Aneroid measurement ..... 120 feet

Bashi Formation:
13. Highly fossiliferous greensand marl with large, very hard calcareous sandstone boulders with the same fossils as matrix ..... 6 feet
12. Green sandy clays and unconsolidated sand, cross-bedded in part, at base; beds of lignite ..... 50 feet
11. Cross-bedded argillaceous glauconitic sands ..... 20 feet
10. Lignite (Smith, covered at time of writer's visit) ..... 2½ feet

Tuscahoma Formation:
9. Laminated sandy clays slightly cross-bedded ..... 12 feet
8. Unconsolidated cross-bedded greenish gray sand ..... 12 feet
7. Blue laminated to thin bedded clay with several 2 to 3-inch sand layers. This bed is exposed along river at waters edge to near Bethel Fault one and one-half miles up stream ..... 20 feet
6. Highly fossiliferous glauconitic sandy marl with large concretionary boulders. Large *Voluta newcombiana* typical), *Turritella mortoni*, *Rostellaria trinodifera*, *Protocardia niccoletti*, etc. in lower part with *Venericardia planicosta*, *Ostrea compressirostra*, etc. in upper portion ..... 6 to 10 feet
5. Alternating layers 4 to 6 inches thick of glauconitic sand and sandy laminated clay (only upper 10 feet well exposed) ..... 25 feet
4. Bluish sandy clay marl with fossils ..... 5 feet
3. Gray sandy laminated clays ..... 50 feet
2. Greensand with fossils (Smith) ..... 1 foot
1. Gray sandy clays to water (Smith) ..... 10 feet

Beds 1 to 7 inclusive exposed at Lower Peach Tree, beds 6 to 14 inclusive exposed at Yellow Bluff. Other exposures of Tuscahoma and Bashi beds occur in the banks of the Alabama from Yellow Bluff down to Johnson's Wood Yard Landing.

The actual contact of the Nanafalia and Tuscahoma formations has not been described along either the Alabama or Chattahoochee Rivers but what appears to be the contact was seen by the writer at three localities in Marengo County. On Geneva Hill, 8 miles southeast of Rembert on the Rembert-Nanafalia road, the Nanafalia is overlain for 20 feet of unconsolidated massive to cross-bedded white to banded yellow sands with a few streaks of black sand. Above this are 18 feet of massive greenish argillaceous sand which is in turn overlain by Lafayette sand and gravel. On the scarp south of Double Creek and 2½ miles north of Nana-

falia 55 feet of Nanafalia marl are overlain by 35 feet of white to yellow massive and cross-bedded sand above which are 20 feet of massive greenish sand with Lafayette sand and gravel covering. In the scarp south of Sweetwater Creek and one mile south of the village of Sweetwater a 40-foot bed of white to yellow sand immediately overlies the Nanafalia with greenish sand next above for 20 feet, and laminated sand clay following. The last mentioned bed is the typical material of this formation in other localities. Thus at least 25 to 40 feet of clean white to yellow sand should be added to the base of the Lower Peach Tree bed in order to complete the section. It is possible that a small thickness of other strata is missing but certainly very little.

Good exposures of strata that evidently belong to the Tuscahoma formation are exposed in road cuts on the hill south of Horse Creek, one mile north of Putnam. The section here includes 160 feet of strata which, with the 45 to 65 feet of beds near Geneva and south of Sweetwater, probably include all of the Tuscahoma. Southward from Geneva Hill to Nanafalia the white sand bed and the overlying greenish sand and sandy clay seem to be either flat or slightly folded. Certainly the normal south dip does not prevail. It appears that in a distance of nine miles south from Geneva Hill the two lowest Tuscahoma beds have just dipped below the surface. Southward from Putnam the Tuscahoma strata dip probably at a rate less than normal and finally go beneath the Bashi strata in the scarp south of Bashi Creek, 8 miles south of Horse Creek.

Thus we have in the sections along the Alabama River a total of 145 feet of strata which, with the lower beds overlying the Nanafalia in Marengo County, gave a total thickness of approximately 200 feet. If the Geneva Hills and Sweetwater sands are classed with the Nanafalia formation it will then have a thickness of 150 to 170 feet in Marengo County and the Tuscahoma 160 to 175 feet, which more nearly agrees with the Alabama and Tombigbee River sections.

The characteristic fossils of the Bell's Landing marl which, about 42 feet below the top of the Tuscahoma, are very large *Venericardia planicosta* (four inches in diameter) and *Voluta newcombiana* about four inches long and one and one-half inches in diameter. *Rostellaria trinodifera* and

many others are also present in the Bell's Landing and lower marls.

BASHI FORMATION.

The Bashi Formation, named by Smith for Bashi Creek, tributary to the Tombigbee River, is the next group of beds in stratigraphic succession above the Tuscahoma Formation. The Bashi consists of a six-foot fossiliferous greensand marl bed containing large concretionary boulders of calcareous sandstone underlain by about seventy feet of gray sandy clays, unconsolidated sands and cross-bedded glauconitic sands with several thin lignite beds in the middle part, and a two to three-foot stratum at the base. The total thickness is from 75 to 80 feet, the complete succession being exposed in Yellow Bluff on the Alabama River and are described in the composite section on page 153. These strata are also exposed three to six miles below Bell's Landing on the Alabama River, on the Tombigbee River at Wood's Bluff and in the bluffs along Bashi Creek in northern Clarke County. Some 45 feet of strata which Langdon refers to the Bashi, outcrop along the Chattahoochee River; see Chattahoochee River section by Landon.

Aldrich has recognized about one hundred species in the Bashi among which are *Pseudoliva vetusta, Dentalium microstria, Venericardia planicosta, Leda protexta, Protocardia nicoletti and Nucula ovula.* Sharks' teeth are also present.

HATCHETIGBEE FORMATION.

The Hatchetigbee Formation lying next above the Bashi was named by Smith for a bluff of that name on Tombigbee River. He includes all the strata between the case of the Claiborne and the Bashi marl in this series of beds, which is given a thickness of 170 to 175 feet along the Tombigbee River. On the Alabama River the formation is apparently somewhat thinner, probably 150 to 160 feet. At Johnson's Landing, six miles below Bell's Landing, the Bashi formation dips below the river. At Welch's Bluff, three and one-half miles down the dip from Johnson's Landing 100 feet of Hatchetigbee strata are exposed. Based on a dip of thirty feet per mile there would be 50 to 60 feet of Hatchetigbee beds below the water level at Welch's Bluff giving a total thickness of 150 to 160 feet. These strata are poorly exposed at Yellow Bluff.

Section of Hatchetigbee Strata at Welch's and Yellow Bluffs, Alabama River and L. & N. Tunnel, Monroe County.

13. Bluish green clay along undulating surface of bed below. Lignitic pebbles and lignitic clay marks slight unconformity between Claiborne and Wilcox ..... 2 inches
12. Bluish green compact very sandy clay ..... 2½ feet
11. Bluish green compact clay with clear quartz grains ..... ½ foot
10. Blue Laminated clay, carbonaceous ..... 17 feet
9. Highly fossiliferous greensand marl. Fossils well developed ..... 1 foot
8. Blue laminated clay ..... 8 feet
7. Fossiliferous greensand marl. Fossils very numerous in upper five feet: *Venericardi planicosta. Leda protexta, Corbula nasuta, Ostrea* similar to *Ostrea vicksburgensis, Turritella carinata, Dentalium*, sharks' teeth, etc. ..... 12 feet
6. Blue laminated clay, slightly sandy in streaks ..... 20 feet
5. Highly fossiliferous glauconitic sandy marl. Indurated boulders. Fossils similar to bed 7 but smaller ..... 6 feet
4. Gray to blue laminated sandy clay ..... 20 feet
3. Lignite ..... 1 foot
2. Laminated, sandy, glauconitic clay with boulders at water's edge ..... 15 feet
1. Gray to blue laminated clays, sandy clays and clay ..... 50-55 feet

Bed No. 1 exposed in Yellow Bluff, beds 2 to 10 inclusive exposed in Welch's Bluff and beds 11 to 13 inclusive exposed at north end of L. & N. Tunnel, Monroe County.

Smith* has described sections on the Tombigbee River at Hatchetigbee, White's Bluff, Davis Bluff and McCarthy's Ferry that are entirely similar to the section given above, but totaling 170 to 175 feet. Langdon' describes thirty feet of "gray sands interlaminated with light colored sandy clays" below Claiborne Buhrstone on Persimmon Creek, 4 miles south of Georgiana, which is correlated with the Hatchetigbee. He also describes 50 feet of sands and sandy clays below the Claiborne Buhrstone in Section 17, Township 7, Range 15 East, Butler County and thirteen feet of sands at Abbeville as being in the Hatchetigbee. On the Chattahoochee River Langdon found only ten feet of gray lignitic sandy clay at the mouth of Yantayabba Creek, which he considered to be the Hatchetigbee.

Thus we find that the Hatchetigbee Formation reaches its greatest development in the western part of the State and gradually thins to ten feet or more on the Chattahoochee River. The belt of outcrop of the beds has no particular topographic characteristics being generally a rolling to rather flat, monotonous country.

*"Geology of the Coastal Plain of Alabama," Smith, Johnson and Langdon, Alabama Geological Survey, 1894.

CLAIBORNE GROUP.

The Claiborne Group of formations in Alabama, which immediately overlies the Wilcox Group, has been subdivided into three formations, from the upper down, as follows:

3. *Gosport Greensand;* fossiliferous sands.
2. *Lisbon Formations;* calcareous fossiliferous sands and fossiliferous greensand marls.
1. *Tallahatta Buhrstone;* soft greenish (white to yellow when oxidized and dry) siliceous claystone with frequent hard ledges in upper portion. The hard silicified ledges are highly fossiliferous while the claystone has scattering fossils.

The Claiborne beds cross the entire State from Henry County on the Chattahoochee River to Choctaw County on the Mississippi line, coming to the surface in a belt from eight to eighteen miles in width, reaching the maximum in Henry, Conecuh and Washington Counties. The Hatchetigbee anticline in Clarke, Choctaw and Washington Counties is encircled by a belt of Claiborne not connected with the main belt of outcrop while an inlier of Claiborne occurs around the town of Geneva in Geneva County.

From Conecuh County westward into Mississippi the surface terrane of the Claiborne is characterized by a very rugged topography caused by the resistance to weathering and erosion of the indurated ledges in the Tallahatta Buhrstone. The hills frequently reach a height of 300 to 400 feet above the main drainage levels and form, in the broader interpretation, cuestas with a very abrupt scarp on the north side and long gentle dip slopes to the southward. This dip-slope plain has in most cases been rather highly dissected by southward flowing streams. These topographic features have formed many excellent exposures of the strata. Eastward from Conecuh County the Claiborne terrane lacks distinctive topographic features being primarily flat to rolling land with the only exposures in road and railroad cuts and along the stream channels.

TALLAHATTA BUHRSTONE.

The Tallahatta Buhrstone, originally called "Buhrstone" by Tuomey and later "Tallahatta Buhrstone" by Smith, lies directly in the Hatchetigbee formation of the Wilcox Group with possibly a very slight unconformity between as indicated by the wavy line of contact and the lignitic pebbles in the exposure at the L. & N. tunnel, Monroe County. The

beds are composed of greenish, siliceous claystones with frequent thin fossiliferous calcedonized strata in the upper portion. Dr. Smith* has recognized a thickness of about 300 feet along the Tombigbee River, while the writer obtained a section of 150-155 feet on the Alabama River computed from actual exposures and measured dips. At Welch's Bluff the base of the Tallahatta is 100 feet above mean low water and at Lisbon Bluff the top is 10 feet above water; the distance between the two bluffs being about 8 miles across the strike of the beds. The measured dip is 30 feet per mile, which was checked by exposures in several bluffs between. The following section is roughly descriptive of the strata.

Section of Tallahatta Buhrstone on Alabama River from Welch's Bluff to Lisbon Bluff.

7. Lisbon formation.
6. Bluish clay with rope-like concretions of clayey sandstone. Placed by Smith at top of Tallahatta (Lisbon Bluff) ..... 12 feet

Bluff at mouth of Silver Creek:

5. Exposure covered, boulders hard claystone and silicified fossiliferous rock ..... 30 feet
4. Claystone (greenish when unoxidized and wet, white on dry exposures) with some glauconitic and a very hard ledge ..... 10 feet
3. Ledge of calcedonized fossiliferous stone ..... 1-2 feet

Welch's Bluff.

2. Indurated thick-bedded claystone, cream colored, a few fossils ..... 20 feet
1. White (weathered, dry) claystone with parallel to conchoidal fracture, generally banded with yellow. A few hard fossiliferous ledges ..... 80 feet

Total thickness of Tallahatta ..... 154 feet

Hatchetigbee below.

At Welch's Bluff the exposure is in a vertical bluff that prevents a close examination. An excellent section of the Tallahatta that may be examined in detail showing the lower 108 feet of the strata are exposed at the north mouth of the L. & N. tunnel in northern Monroe County. Other excellent exposures occur throughout the belt in Monroe and Clarke Counties. The claystones are generally glauconitic and frequently sandy with hard, irregular ledges occurring at intervals of 10 to 20 feet. On a fresh unweathered surface they are always a light greenish color, which changes to a white or cream color with yellow band-

*Smith, Eugene A., op. cit.

ing on oxidation. The hill slopes where clean exposures are covered by wash are practically always littered with fragments and large boulders of the claystone and boulders of the calcedonized fossiliferous rock. The materials weather to a tough yellow clay soil quite similar in appearance to the soil derivative of the upper clays of the Nanafalia formation. In fact the Claystone of the Tallahatta is quite similar in general appearance to the more indurated clays of the upper Nanafalia but not readily mistakable.

Hopkins* estimated the thickness of the Tallahatta to be about 200 feet on the northern slope of the Hatchetigbee anticline and 20 feet near the Lower Salts Works on the Tombigbee River, Washington County. This considerable thinning to the southward is evidently related to the formation of the anticline.

Dr. Smith† has described sections of the Tallahatta Buhrstone on the Tombigbee River at McCarthy's Ferry, where he recognized 250-270 feet, at White Bluff, where he found 115 feet, and at Hatchetigbee Bluff, where the upper 20 to 30 feet are Tallahatta.

Eastward from Conecuh County to the Chattahoochee River the Buhrstone seems to lose its most distinguishing features and is interbedded with strata resembling the Lisbon formation on the Alabama River. Langdon's section is descriptive of the occurrence on the Chattahoochee River (see page 220).

While there appears to be a very slight unconformity between the Hatchetigbee and the Tallahatta formations, there was at the same time a gradual transition from the lower formation to the upper separated by a short period of shallow water as evidenced by the sandy character of the upper three feet of the Hatchetigbee formation and the sand bed at the base of the Tallahatta as seen at the L. & N. tunnel. The wavy top of the Hatchetigbee, together with the lignitic pebbles possibly originated in a short time interval of very shallow water rather than from dry land erosion.

LISBON FORMATION.

The Lisbon formation though apparently merging with the Tallahatta Buhrstone to some extent in eastern Alabama,

*Hopkins, Oliver B., Oil and Gas Possibilities of the Hatchetigbee Anticline, Alabama. U. S. G. S. Bull. 661-H, 1917, page 291.

†Smith, E. A., op. cit., p. 143.

persists across the entire State as a distinct lithologic unit composed of calcareous sands, clays and glauconitic sands containing abundant fossils, the most prominent of which is *Ostrea sellaeformis*. The thickness of the unit is about 140 feet on the Alabama River. The section on the Tombigbee is incomplete though Hopkins* intimates a thickness of 200 feet for the Gosport and Lisbon combined on the north side of the Hatchetigbee anticline and 40 feet on the south side. On the Chattahoochee River Langdon refers 60 to 75 feet of strata to the Lisbon, while in the strata which he refers to the Buhrstone, there is considerable material entirely similar to the Lisbon.

The following section by E. A. Smith and L. C. Johnson† and checked by the writer, is descriptive of the complete section of Lisbon and Gosport:

Section of Claiborne and Lisbon Bluffs.

20. Red loam, sand and pebbles ..... 35-40 feet
19. Argillaceous limestone, with greenish grains ..... 45 feet
18. Indurated ledge, with *Scutella lyelli* ..... 3 feet
17. Coarse, ferruginous sand, calcareous below; indurated ledge at base ..... 6 feet
16. Claiborne fossiliferous sands; ferruginous, with shells; laminated lignitic clays, with leaf impressions, and thin seams of lignite in places in upper part ..... 15-17 feet
15. Bluish green, glauconitic sandy marl, containing *Ostrea sellaeformis*, in part indurated ..... 3-4 feet
14. Calcareous, bluish gray clay, with a few badly preserved fossils, passing downward into a greenish, glauconitic sandy marl, containing great numbers of young shells of *Ostrea sellaeformis* and a few *Pectens*, the two together, clay and sand ..... 18 feet
13. Light gray, calcareous clay, similar to the preceding, with hard ledges at top and bottom, in all ..... About 7 feet
12. Light yellowish gray, calcareous sands, with *Pectens* and *Ostrea sellaeformis*, the lower half indurated, containing casts of univalve shells ..... About 5 feet
11. Light yellowish gray, calcareous sands, with thin beds of more clayey texture and with five or six hard, sandy ledges at intervals; the sand is, in places, loose and crumbling, and quite fossiliferous, with *Ostrea sellaeformis*, *Pecten deshayesii*, fragments of *Scutella lyelli*, etc. Lower 8 feet a bluish, clayey sand ..... About 27 feet
10. Bed of greensand, with perfect shells and fragments of *Ostrea sellaeformis*, etc. ..... About 3 feet
9. Dark blue, nearly black, sandy clay ..... 2 feet
8. Bluish green, clayey sands, few fossils above, but highly fossiliferous below and rather more clayey, *Venericardia planicosta*, *Nucula magnifica*, *Ostrea sellaeformis*, *Arca*

*Hopkins, O. B., op. cit.
†Op. cit., pp. 708-709, Geology of the Costal Plain of Alabama.

rhomboidella, Voluta sayana, Turritella mortoni, Turritella bellifera, etc.....10 feet
7. Dark grayish blue greensand, peculiar small form of *Venericardia planicosta,* large *Turritella mortoni,* etc., 6 feet at Claiborne but 10 feet at Lisbon.....
6. Hard, sandy ledge.....8 inches
5. Calcareous, clayey sands, light yellowish to white color..... 8 feet
4. Coarse, ferruginous sands, with numerous fossils..... 3 feet
3. Light yellow sand, capped with a hard ledge, forming perpendicular bluff.....15 feet
2. Blue, glauconitic sands, probably a modification of 18..... 5 feet
1. Bluish black clay; top of Buhrstone contains curious concretions of sandy clay, like interlacing roots.....

Other exposures of Lisbon and Gosport beds occur at Coffeeville Landing, Tombigbee River, four miles west of Gilbertown, Section 33, Township 11 N., Range 4 W., and near Oven Bluff, Tombigbee River. Exposures of the upper Lisbon beds also occur on Choctawhatchee River near Geneva.

GOSPORT GREENSAND.

The Gosport greensand was so named by Dr. Eugene A. Smith from the type locality at Gosport Landing, five miles below Claiborne on the Alabama River. The most characteristic feature of this bed is the abundant beautifully preserved fossils which it carries among which are *Cytherea aequorea* in great numbers in the upper portion, *Pectunculus broderipii,* Lea, *Rostellari velata,* Conrad, *Voluta defranckii,* etc., etc. The fossil bed has been traced through Washington, Choctaw, Clarke and Monroe Counties, but does not seem to be present out of this area. The stratigraphic position of the Gosport is shown in the Claiborne section.

JACKSON FORMATION.

The "White Limestone" of Tuomey and of Smith included all of the limestone of Upper Eocene and Oligocene age which are now divided into the Jackson Formation at the base, the Vicksburg Group in the center, and the Salt Mountain or Coral Limestone at the top. The lowermost of the three is the upper formation of Eocene age while the upper two are lower Oligocene. Smith included the three formations under one group because of the lithologic and paleontologic similarity of the entire section of strata though

he at the same time recognized the presence of the Jackson and Vicksburg formations of Hilgard and considered the Salt Mountain Formation as a distinct unit. Cooke* has made a study of the Jackson and Vicksburg from Mississippi across Alabama to Florida and Georgia and has made a somewhat closer subdivision of the strata. Hopkins† has also made a study of the Jackson and other St. Stephens strata in Clarke, Choctaw and Washington Counties, surrounding the Hatchetigbee Anticline.

The Jackson formation (Ocala formation of Cooke) of central Georgia‡ consists of 40 to 50 feet of soft white Bryozoan limestone containing a variety of fossils most typical of which are *Pecten perplanus, Orbitoides mantelli* and *Periarchus pileus-sinensis* (*Scutella lyelli*). Lying over the soft Bryozoan limestone is a six-inch to two-foot bed of hard semi-crystalline highly fossiliferous limestone which is in turn overlain by 50 feet, more or less, of Fuller's earth which, going down the dip of the strata, increases in calcareousness until it has become an argillaceous limestone in the area near Albany, Georgia. Southwestward from Albany to Saffold a few exposures occur in Calhoun and Early Counties near Arlington that are probably referable to the Jackson. A test hole here found a thickness of 60 feet of rather hard, massive, granular white limestone with a few poorly preserved fossils. Southwestward to the Alabama line no further exposures have been found. On Chattahoochee River, 2 miles below Gordon, Langdon describes 25 to 30 feet of weathered material containing numerous *Periarchus pileus-sinensis*(?), *Pecten nuperus*, etc. This strata evidently belongs to the Jackson. It seems that there might easily be a somewhat greater thickness here than has been described since the exposures are not particularly good.

Westward into Alabama the character of the Jackson changes to a series of less calcareous beds as indicated by the following section which is evidently referable to the Jackson:

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*Cooke, C. W., "The Age of the Ocala Limestone," U. S. G. S., Prof. Paper 95-I, pp. 114-117.

†Hopkins, Oliver B., op. cit.

‡Brantly, J. E., "Limestones and Marls of the Coastal Plain of Georgia," Georgia Geological Survey, Bull. 21.

Section 10 miles northeast of Geneva, Alabama, Section 19 or 20, Township 2, Range 23 East.

8. Yellow and blue argillaceous sand which weathers to a deep red ..... 20-30 feet
7. Coarse red sands with abundant *Pecten perplanus* ..... 2 feet
6. Smooth greenish Fuller's earth-like clay ..... 3 feet
5. Bluish clay with streaks and pockets of glauconitic and silicified fossils ..... 2 feet
4. Calcareous glauconitic sandstone ..... 3 feet
3. Yellowish glauconitic sand packed with fossils, *Pecten perplanus, a small Ostrea* (*sellaeformis*? young) and *Orbitoides* ..... 3 feet
2. Soft cream colored sandy limestone with great numbers of small *Orbitoides* (*mantelli?*) ..... 5 feet
1. Soft argillaceous white limestone ..... 4 feet

Lithologically these strata resemble very closely those of the Claiborne Lisbon formation. A similar section on the Pea River has been described by Langdon,* of which he is doubtful as to the exact stratigraphic position, whether Jackson or Claiborne. Other exposures of probably Jackson age occur in Covington and Conecuh Counties and on west to the Mississippi line.

Smith† has described the following section showing 60 feet of Jackson on the Alabama River.

Strata exposed in continuous bluffs between Marshall's Landing and Rattlesnake Bluff, just below Claiborne, showing relative positions of the White Limestone and the Claiborne sands, Alabama River.

Marianna Limestone:
9. Orbitoidal White Limestone of usual character ..... 10 feet

Jackson Formation:
8. White Limestone, containing great numbers of *Scutella lyelli* and other echinoderms ..... 10 feet
7. Calcareous clay in two beds of five feet each separated by three feet of soft, earthy White Limestone. Below this a ledge of hard limestone three feet and eight feet of blue clay with fucoids, becoming more calcareous below, in all ..... about 20 feet
6. Ledge of hard, white limestone, followed by twenty feet or more of argillaceous, soft, white limestone at intervals. Resembles the rotten limestone of Cretaceous formation ..... About 25 feet
5. Bed of *Scutella lyelli*, in three layers, the middle one ferruginous ..... 3 feet
4. Coarse ferruginous sand, calcareous below, hard ledge at bottom ..... 6 feet

Claiborne Group:
3. Claiborne ferruginous, fossiliferous sands, the counterpart of those at Claiborne Bluff ..... 10-12 feet

*Op. cit., page 381.
†Op. cit.

2. Calcareous, sandy clay, with hard ledge in middle ..... 6 feet
1. Sandy, clay marl, with *Ostrea sellaeformis*, four or five hard ledges passing into greensand below ..... 12 feet

Cooke* describes a Jackson and Claiborne section in Choctaw County as follows:

Section at Willow Branch, 4 miles from Silas, Alabama.

Post-Vicksburg:
13. Red sand to top of hill; about ..... 50 feet

Jackson Formation:
12. Drab calcareous clay with white calcareous concretions ..... 25 feet
11. Yellowish marl with *Pecten perplanus* and *Periarchus pileus-sinensis?* Indurated in lower portion ..... 11 feet
10. Fine-grained yellow sand ..... 21 feet
9. Argillaceous yellow sandy marl with shells; grades into the underlying bed ..... 9 feet
8. Greenish-yellow clay with shells, forming a gentle slope, about ..... 50 feet

Claiborne Group:
7. Hard gray indurated marl with small grains of glauconite and a few fragmentary shells ..... 1½ feet
Note—The measurements of the beds above No. 7 were made on the south side of the valley; of those below, on the north side.
6. Reddish-brown ferruginous glauconitic sand containing casts of mollusks, with a 1-foot shell bed at bottom ..... 7 feet
5. Dark gray to black sandy clay with shells ..... 3½ feet
4. Laminated gray sand and clay with *Oreodaphne inequilateralis and Mespiladaphne columbiana* ..... 7 feet
3. Dark green to black glauconitic sand loaded with Claiborne shells ..... 2 feet
2. Dark green to black, somewhat sandy clay. Weathers with fissile parting resembling "coal Blossom" ..... 5 feet
1. Reddish-brown ferruginous sand to stream bed (1 to 2 feet concealed at bottom) ..... 10 feet
This section shows 116 feet of Jackson.

The Jackson formation contains mostly limestone in Georgia and Florida, getting less calcareous to the west until in Alabama and Mississippi it is made up primarily of calcareous clays and limestone and glauconitic sands and clays. In Georgia the hard Jackson limestones cause a steeply rolling, rugged topography with cuestas having their steep slope on the north and the gentle slope to the south. In the Alabama, however, the soft nature of the beds give rise to a rather monotonous topography except where associated with the ridges and hills in the Claiborne belt and the hard beds of the Vicksburg. Characteristic fossils of the Jackson are *Periarchus pileus-sineuris, Orbitoides,*

*Cooke, C. Wythe; op. cit.

Ostrea sellaeformis, Pecten perplanus (typical), etc., etc. *Zeuglodon centoides* bones are found in the Jackson in what is known as the "Zeuglodon bed."

OLIGOCENE.

The line of division between strata of Eocene and Oligocene age has been placed between the Jackson formation and Vicksburg Group. The latter lies conformably upon the former and from the very similar nature of the materials of the two series of beds it is quite evident that the conditions of sedimentation were entirely similar. In western Alabama clays and marls of the Red Bluff Clay member of the Vicksburg rest on clays and marls of the Jackson. Along the Alabama the two formations are composed primarily of more or less impure limestones which persist eastward into Georgia and Florida, but becoming more pure. The faunal life of the two seas was also quite similar but there were distinctive species in each, upon the basis of which the line of division was so placed.

The Oligocene in Alabama is composed of the following formations, in descending order:

Hattiesburg Clay (Grand Gulf).—Blue and gray clays and sands, of non-marine origin. Thickness near 300 feet.

Catahoula Sandstone (Grand Gulf).—Sandstones, sand and greenish clays of probable non-marine origin. Thickness near 200 feet.

Salt Mountain Limestone.—Hard massive limestone composed largely of coral, about 100 feet.

Vicksburg Group.—Including Marianna limestone and the Red Bluff Clay. Hard limestones, soft argillaceous limestones, marl and clay. Thickness 125 to 200 feet. Dr. Smith* formerly included the Catahoula sandstone and Hattiesburg clay together as the Grand Gulf Group, but later geologists and paleobotanists† have separated the group into the above named formations. In Alabama the Grand Gulf is very difficult of separation except upon minute paleontologic studies and therefore it seems that the term "Grand Gulf" of E. W. Hilgard is a fitting one to retain for less minute and detailed descriptions. Eastward into Florida and Georgia the Hattiesburg and Catahoula apparently

*Op. cit., "Geology of the Coastal Plain of Alabama.

†Matson, C. M. and Berry, E. W. "The Catahoula Sandstone and Its Flora." U. S. G. S., Prof. Paper 98-M. 1916.

merge into the Alum Bluff Clays and the Chattahoochee Limestone.

VICKSBURG GROUP.

The Vicksburg Group included by Smith in the "St. Stephens Limestone" has been separated into two parts, namely, the Marianna limestone at the top and the Red Bluff Clay of Hilgard at the base. In turn the Marianna limestone, named for the type locality at Marianna, Florida, has been subdivided in western Alabama into the Glendon limestone above and the Chimney Rock below by C. W. Cooke. E. A. Smith likewise recognized and described these distinctive beds but included them under his group name "St. Stephens Limestone."

The St. Stephens Group including the Jackson and Vicksburg forms the surface in a belt from ten to twenty-five miles wide extending from the Mississippi line in southwestern Choctaw County, where the belt is narrowest, to the southeastern corner of the State. The dip varies from probably twenty-five feet per mile in western Alabama to as little as ten feet per mile near the Chattahoochee River. Over this entire area the Vicksburg and Jackson terrane is covered with sands and clayey sands of later age which obliterate any characteristic soils which might have been derived from the calcareous beds. The only exposures, with a few exceptions west of Monroe County, are in the immediate stream banks and beds. The limestones give rise to a rugged topography in areas in western Alabama where the harder Glendon limestone is prominent while east of Monroe County the surface is generally lacking in distinctive features. The thickness of the Vicksburg varies from about 140 feet in West Alabama to possibly 175 feet or more in southeast Alabama and Florida.

RED BLUFF CLAY.

The lowest beds of the Vicksburg consisting of glauconitic marls at the base and clays with gypsum crystals and impure limestones above, have been called Red Bluff from its exposures along Chickasaway River in Mississippi.* At

*Lowe, E. N. Mississippi: Its Geology, Geography, Soils and Mineral Resources. Miss. Geol. Survey, Bull. 12, 1919, pp. 89-90.

its type locality in Mississippi the Red Bluff attains a thickness of 60 feet while in western Alabama it has thinned to 30 or 40 feet and along the Alabama River to probably little more than 15 feet. In eastern Alabama no typical Red Bluff beds have been found.

The fossils of the Red Bluff clay are those characteristic of the Vicksburg Group, e. g., *Pecten poulsoni* (typical), *Spondylus dumosus, Ostrea vicksburgensis,* etc., etc. Cooke† has described the following section, which shows the relation between the Red Bluff clay and the Jackson formation.

Section three and one-half miles southeast of Cullomburg, Alabama.

8. Concealed to top of hill; about ..... 50 feet

Red Bluff clay member of Vicksburg limestone:

7. Very plastic gray clay with crystals of gypsum. Contains *Pleurotoma plutonica?, P. congesta, Busycon, spiniger, B. nodulatum, Phos macilentus, Ostrea vicksburgensis, Pecten aff. P. poulsoni, Spondylus dumosus, Corbula perdubia* ..... 22 feet

6. Green-gray or buff glauconitic marl, consisting of grains of green glauconite the size of bird shot, in a white calcareous clay matrix. In the upper portion are several discontinuous ledges, and at the top is a more persistent ledge. Contains *Balanophyllia caulifera, Ostrea vicksburgensis, Pecten cocoanus. Pecten aff. P. poulsoni, Spondylus dumosus, Corbula sp.,* and *Astarte triangulata.* The *Ostrea* and *Spondylus* weather out of the lower 2 feet in great abundance but are difficult to see in the unweathered material ..... 9 feet

Jackson Formation:

5. Stiff calcareous clay, yellow or buff on weathered surface, bluish green on damp fresh surface. Contains small irregular concretions. Merges into the overlying bed ..... 8 feet

4. "Zeuglodon bed," buff argillaceous marl, merging into the overlying bed. Forms a gentle slope. Contains Flabellum, *Schizaster armiger, Ostrea falco, O. trigonalis.,* Gryphaeostrea, Pinna, *Modiolus cretaceus, Pecten perplanus, Terebratulina lachryma* ..... 9 feet

3. Gray to yellow, very calcareous, argillaceous marl with some hard ledges. Forms steep slope. *Pecten perplanus, Ostrea trigonalis,* and Bryozoa abundant; other fossils represented by casts ..... 6 feet

2. Yellow calcareous sand with poorly preserved shells and casts of Leda . Some calcareous concretions at base ..... 18 feet

1. Steel-gray sandy calcareous clay; about ..... 3 feet

MARIANNA LIMESTONE.

In western Alabama that portion of the St. Stephens which Smith called "Orbitoidal Limestone" and correlated

†Cooke, C. W. The Age of the Ocala Limestone. U. S. G. S., Prof. Paper 95-I, 1915, p. 116.

with the Vicksburg of Mississippi has been identified as being equivalent to the Marianna of Florida by Cooke.‡ In the Tombigbee River section the upper 12 to 16 feet is a hard semi-crystalline, yellowish limestone which weathers into smooth, irregular rocks locally called "horsebone." This is the Glendon member of Cooke. Underlying this is the soft Orbitoidal limestone or "Chimney rock" which is from 90 to 110 feet thick in the Alabama and Tombigbee River section. Eastward into Florida and Georgia this bed holds its principal characteristics and reaches a thickness of possibly 175 feet in southeastern Alabama and Florida. The fossils present are those in the Red Bluff and abundant *Orbitoides mantelli.* Many other genera are liksewise present. It is well to note that the fossil *Venericardia planicosta* so very typical and abundant in the Wilcox and lower Claiborne formations is comparatively rare in and above the Lisbon formation though existing up into the Vicksburg.

SALT MOUNTAIN LIMESTONE.

The Salt Mountain or Coral Limestone, named by Dr. E. A. Smith for the locality at which it is well exposed, Salt Mountain in Clarke County, consists of beds of hard and soft limestone with very abundant corals. This limestone has only been found in this immediate locality and thereafter seems to be of very local origin and will not enter into the vertical sections in Alabama except as a local unit. Dr. Smith estimated the thickness at 150 feet with which he probably included 15 feet of Vicksburg Glendon. Hopkins has later estimated the thickness to be 80 to 90 feet.

GRAND GULF GROUP.

CATAHOULA SANDSTONE.

The landward limit of the Grand Gulf formations, of which the Catahoula sandstone is the lower member, is a practically straight line extending northwestward from Florida to the northwest corner of Washington County. The Catahoula consists of sandstones, quartzite, sands and clays with the arenaceous sediments representing the much larger proportion of the entire thickness of 200 feet in Ala-

‡Op. cit.

bama as estimated by Matson.* The formation is largely covered by sands and sandy clays of more recent age so that exposures are rather rare and the formation does not extensively determine the character of the soils over the area in which it comes to the surface. Practically all the exposures are confined to the banks of streams. Outcrops are present near Healing Springs in Washington County and near Brewton in Escambia County. The dip of the Catahoula has not been definitely determined but it is probably near 20 feet per mile. The beds are of non-marine origin in western Alabama, becoming of marine origin to the eastward and probably merging in Florida into the Chattahoochee limestone.

HATTIESBURG CLAY.

The upper portion of the Grand Gulf, recognized as being equivalent to the Hattiesburg clay of Mississippi and so named in Alabama, consists of sands, clays, lignitiferous sands and clays and lignites. As is the case with the underlying Catahoula sandstone the surface terrane of the Hattiesburg clay is so covered with sands of the Lafayette and later formations that it has little or no effect on the soils of its area of outcrop. The exposures are very few and then only in the banks of streams crossing the formation. The best exposures to be seen in Alabama are in the vicinity of Roberts in Escambia County. In Western Alabama the formation is probably non-marine but near Roberts L. C. Johnson† found marine fossils. Eastward into Florida and Georgia the Hattiesburg merges into the Alum Bluff clays. Matson has estimated the maximum thickness of the formation in Alabama to be about 300 feet. The normal dip is near 20 feet per mile to the southward.

MIOCENE.

PASCAGOULA FORMATION.

From the nature of the materials along the contact of the Pascagoula and the Hattiesburg and the apparent varying thicknesses it is evident that an unconformity exists between the Oligocene below and the Miocene above. The

*Op. cit.
†Op. cit. Geology of the Coastal Plain of Alabama.

extent of this unconformity has not been determined though it has been recognized by several geologists. The Pascagoula formation consists in the main of blue clays and sands containing fossils, primarily of microscopic size, which indicate a marine origin. The extent and thickness of the Pascagoula has not been definitely determined though Matson* has estimated a thickness of 250 feet and Dr. Smith** determined Miocene fossils at a depth of 735 feet in a well at Mobile, which would indicate a greater thickness. From the information gained by the plotting of well logs in the Mobile vicinity but without the advantage of microscopic examination of the cuttings, the Pascagoula appears to have a thickness of at least 400(?) feet with a dip seaward of upward of 20 feet per mile. As is the case with most of the formations which come to the surface in the southern part of the State, practically the entire formation is obliterated by sands and sandy clays of the Lafayette and later formations. L. C. Johnson† first described and named the Pascagoula formation in Mississippi in 1890. Few, if any, exposures in Alabama are definitely referable to the Pascagoula on the basis of their fossil content, though, from their geographic position, exposures along Chickasabogue and Cedar Creeks belong in this formation.

PLIOCENE-PLEISTOCENE.

LAFAYETTE FORMATION.

Along the Atlantic and Gulf Coastal Plain there is a system of sands, clays and gravels that were originally called "Orange Sand" by Safford, of the early Tennessee Geological Survey, and Hilgard, of Mississippi. They included in their "Orange Sand" sands and clays that ranged in age from probably pre-Pliocene to Pleistocene. Later McGee used the term "LaFayette Formation" to replace the earlier name and at the same time restricting it to apply to deposits of Pliocene and probably early Pleistocene age. Smith and Johnson have used the name in Alabama to apply to Pliocene and possibly early Pleistocene deposits. Matson

*Op. cit.
**Op. cit., p. 93.
†Op. cit.

and Berry‡ have made a later study in which they have further subdivided the Lafayette and abandoning that name for their new name, "Citronelle Formation." In this report the original name "Lafayette" is retained since the character and position of the deposits of Pliocene age and possibly early Pleistocene are of sufficient uniformity and similarity to warrant incorporation under one title.

Following the deposition of the Miocene strata the sea receded to possibly near its present margin during which time the most of the present land area was above water and being subjected to a more or less rapid denudation . The sea then transgressed landward for probably seventy-five to one hundred miles north of the present shore line, during which short time the sands and clays of the near shore Lafayette were deposited (the Citronelle of Matson and Berry). Near the close of the Pliocene, which was very short as far as the present surface formations indicate there must have been a very rapid transgression of the sea to a line probably 200 to 250 miles north of the present shore line, covering a topography very similar to the present but with less marked relief. When the sea had transgressed to its landward limit it was caused to regress rapidly by the elevation of the land area of northern Alabama. This land elevation resulted in swift streams bringing down abundant heavy sediments of sand and gravel depositing them as terraces and deltas and in some cases probably great alluvial fans. At the end of this rapid regression the shore line probably reached its present position. Throughout the Coastal Plain the landward Lafayette covers indiscriminately all of the Cretaceous and later deposits and even overlapping onto the Paleozoics and Crystalline rocks. The appearance is that the upstate Lafayette occupies a fourth and highest terrace. The sands, sandy clays and gravels of the inland portion reach a thickness of 25 to 30 feet and is the common gravel bed material of middle Alabama. Further southward the sheet deposit of Lafayette probably attains a thickness of 200 feet being the high terrace materials along the coast. (The above expressed theory of the origin of the Lafayette does not coincide with the views of Dr. Smith, nor is the writer entirely satisfied with the explanation.)

‡Matson, G. C. and Berry, E. W. "The Pliocene Citronelle Formation." U. S. G. S. Prof. Paper 98-L.

PLEISTOCENE.

UNIVERSITY TERRACE.

After the Lafayette was deposited and the shore line had been disturbed by comparatively slight oscillations, the inland streams had been widening their valleys and forming more or less extensive flood plains. Upon elevation of the land area the streams began to rapidly deepen their channels, leaving the former flood plain as the present University terrace, so named in this report, after a conference with Dr. E. A. Smith, for the typical broad terrace upon which the University of Alabama is located. Montgomery, Selma, Eufaula and Claiborne are likewise on the University or third terrace while it is well defined along the Gulf through middle Mobile and Baldwin Counties.

NORTHPORT TERRACE.

After the streams had cut down for probably 80 to 100 feet they again began to widen rather than to deepen their valleys, forming wide flood plains. Another elevation of the land caused the streams to further deepen their channels leaving the flood plain as the second or Northport terrace, named in this report for the typical terrace on which Northport, Tuscaloosa County, is located. The terrace is further defined as being between the University Terrace and the present flood plains. The University Terrace is from 100 to 160 feet above the present drainage levels while the Northport is about 50 to 75 feet above. The University Terrace is made up of sands and silts with considerable gravel near the crystalline and Paleozoic areas. The red gravels are easily mistaken for Lafayette and in fact are probably in many deposits reworked Lafayette gravel. The Northport Terrace is composed largely of yellowish silts and clays with more or less sand in places.

RECENT.

The First Bottom or present river flood plain deposits consist of silts, sands and gravel dependent in variety primarily upon the nature of the formation composing the drainage areas of the individual streams. The Chattahoochee River above Columbus, Georgia, runs entirely through the Piedmont area of old crystalline and later igneous rocks

and in consequence transports sands and pebbles of various varieties and silts and clays that are principally derivative of decomposed feldspars and other igneous minerals together with clays from the rather complex schists and other metmorphosed sediments of the Piedmont or crystalline area. The sands and pebbles are less worn and rounded than those of streams draining areas of sedimentary rocks because of the shorter distance of transportation.

These materials occur in the flood plain to thicknesses of as much as fifty feet in some instances with the sands and gravels predominating in the lower portion and the clays in the upper part. The clays are normally of a reddish color because of the rather high iron content and the small amount of humus transported with the clay.

The Alabama River drains a considerable area of Paleozoic formations in northwest Georgia and northeast Alabama and a lesser territory in the Piedmont section. Paleozoic beds are mostly limestone and shales with some sandstones while the crystalline rocks are granites, quartzites, schists, and so on. The Paleozoics furnish a relatively finer and more plastic clay with a lower iron content and a more rounded sand and pebble because of the greater distance of transportation, it having been deposited in the old Paleozoic seas and now undergoing further transportation. These materials when redeposited along the stream flood plain and along and in the Gulf of Mexico form beds of rather plastic clays and rounded sands with an admixture of the less plastic red clays and sharper sands from the Piedmont.

The Warrior and Tombigbee Rivers drain areas of the Paleozoic rocks as well as Cretaceous and later formations and carry a burden of less clay in proportion to the sand.

All of these streams drain large areas in the Coastal Plain and are again moving materials that were derived from the areas of the present upper reaches of the drainage channels and deposited under conditions somewhat analogous to the present.

Along the Coastal strip the materials being deposited are sands obtained from the mouths of the various streams entering the Gulf and moved and redeposited by the action of the waves. The silts are being deposited along the Coastal strip beyond the limit of the stream currents.

These first bottom deposits occupy comparatively narrow strips along the rivers and the Gulf Coast and probably attain a thickness in places of fifty or sixty feet. They are readily distinguished by their position along both the rivers and the coast.

STRUCTURE.

The Coastal Plain area of Alabama is in general aspect a monocline, being a comparatively small segment of that great monoclinal nose which is described about the southwestern extension of the Cumberland Paleozoics, the Appalachian Mountains and the Piedmont area, which we will call the Appalachian Peninsula. The normal direction of the dip about the nose is from southeast on the Atlantic seaboard to northwest in Tennessee and Kentucky or at the normal direction to the short line about the peninsula. The degree of inclination of the old Cretaceous sea floors of Pre-Cambrian and Paleozoic rocks can be determined only where wells, which are few in number, have been drilled through the mantle of Coastal Plain materials and into the basement rocks below. In Alabama the Cretaceous sea floor of Pennsylvanian rocks probably had an inclination of slightly more than 30 feet per mile to the southwest while the metamorphosed rocks under the Cretaceous sea had a southerly inclination of upward of 40 feet per mile. From Louisville, Georgia, north to the Fall Line the basement rock surface dips from 50 to 60 feet per mile, S. 70° E.

The dip of the Cretaceous strata varies from 35 to 40 feet per mile in the lower part of the series to 30 feet per mile in the upper portion. On the eastern side of the State the direction of dip is south while in western Alabama and eastern Mississippi the direction is southwest. Southward toward the Gulf from the formations of Cretaceous age the dip of the strata decreases to a probable minimum rate of nearly 20 feet per mile along the coast. Based on the data secured from the logs of numerous wells drilled in the area south of the outcrop of the Selma Chalk the dip of the base of this formation is thirty-five feet per mile while measured dips in the Eocene show that the formation have an inclination approximating 30 feet per mile. Along the coast the dips cannot be definitely determined.

There is present in the southern portion of Alabama a system of folds and faults having an axial trend of about thirty degrees north of west. This trend can be traced southeastward almost across the State of Florida and westward into Mississippi, and is parallel to the axes of certain mountain and fault systems of the southwest which is suggestive of a contemporaneous origin from the same tectonic forces. This is also the approximate direction of the axes of the Red River folds of Northern Texas. A second system of folding in southern Alabama, while not as yet definitely determined, seems to have an axial direction only slightly west of north. It is possible that this system is more closely related to the major series of folds than the apparent trend would indicate. All of these movements are post-Eocene and probably comparatively recent. A very recent movement has caused the drowning of the mouth of the Mobile River and the consequent result of a rather shallow syncline. The several known folds of southern Alabama will be described very briefly on the next succeeding pages.

Geneva Structure.—The normal surface terrane of the Claiborne formation in southeast Alabama crosses the southern portion of Coffee County where it dips to the southward below the surface at the rate of about 25 feet per mile, being covered along the southern border of the county by the Jackson and Vicksburg formations. The Claiborne is again exposed in the creeks and rivers in the immediate vicinity of the town of Geneva. The Claiborne passes below the surface in Coffee County on Choctawhatchee River. With the usual rate of dip of 25 feet per mile the normal position of the Claiborne would be 250 feet below the surface at this latter point which is indicative of a fold or uplift of the strata. No contact of different beds or bedding planes can be observed along the streams where the Claiborne is exposed from which dips can be read to delineate the structures. Also there is no bed in the Claiborne on this uplift that can be safely used as a key horizon and traced throughout the various exposures. Outcrops of beds referable to the Claiborne occur in all of the streams close to Geneva and though their exact horizon in the Claiborne cannot be determined they are evidently of the upper portion since the overlying Jackson and Vicksburg formations closely encircle the area in which the Claiborne is exposed.

In the banks of Double Bridges Creek one mile north of Geneva, where the Bellwood road crosses, there are good exposures of calcareous sands containing large silicified shells of *Ostrea sellaeformis*. Overlying this is white sand of terrace origin. On the Dothan road where it crosses Choctawhatchee River the same beds are exposed. In the road cut a short distance northeast of the river and 50 feet above there are large boulders of silicified limestone containing *Orbitoides*, *Pecten*, etc., that is probably referable to the Vicksburg though occupying the stratigraphic position of the Jackson. This position of the boulders may have resulted from the softer Jackson having been eroded away, letting the boulders of more resistant flint rock work down into its horizon. On the road to the east of and parallel to Choctawhatchee River, six to ten miles southeast of Geneva, there are exposures of blue argillaceous sands underlain by fossiliferous calcareous sands and argillaceous limestones that are referable to the Jackson. In the country east of this road are frequent large boulders of fossiliferous silicified Vicksburg limestone. At Hall's Mill on Beaver Dam Creek, some four or five miles northwest of Geneva, there is an exposure of fossiliferous sandy limestone that is apparently about the top of the Claiborne or the base of the Jackson. The banks of the Pea River near its confluence with the Choctawhatchee expose some ten feet of sandy limestone devoid of fossils which from its stratigraphic position and lithologic character is referable to the Claiborne.

The area around Geneva in which the Claiborne comes to the surface, is some six miles in length north and south and slightly less east and west. The elevation of the top of the Claiborne above its normal position is somewhat more than 250 feet.

Lower Peachtree Anticline, Figures 25 and 26, so named by Smith from the village of Lower Peachtree on the Alabama River in southwestern Wilcox County, which is situated approximately on the crest of the fold, may be best determined in cross-section along the Alabama River from Yellow Bluff to a point one mile below Bell's Landing. At the edge of the water at Yellow Bluff during low water stages of the Alabama River, there is exposed a marl bed of the upper portion of the Tuscahoma formation that is characterized by very large *Voluta newcombiana* and *Venericar-*

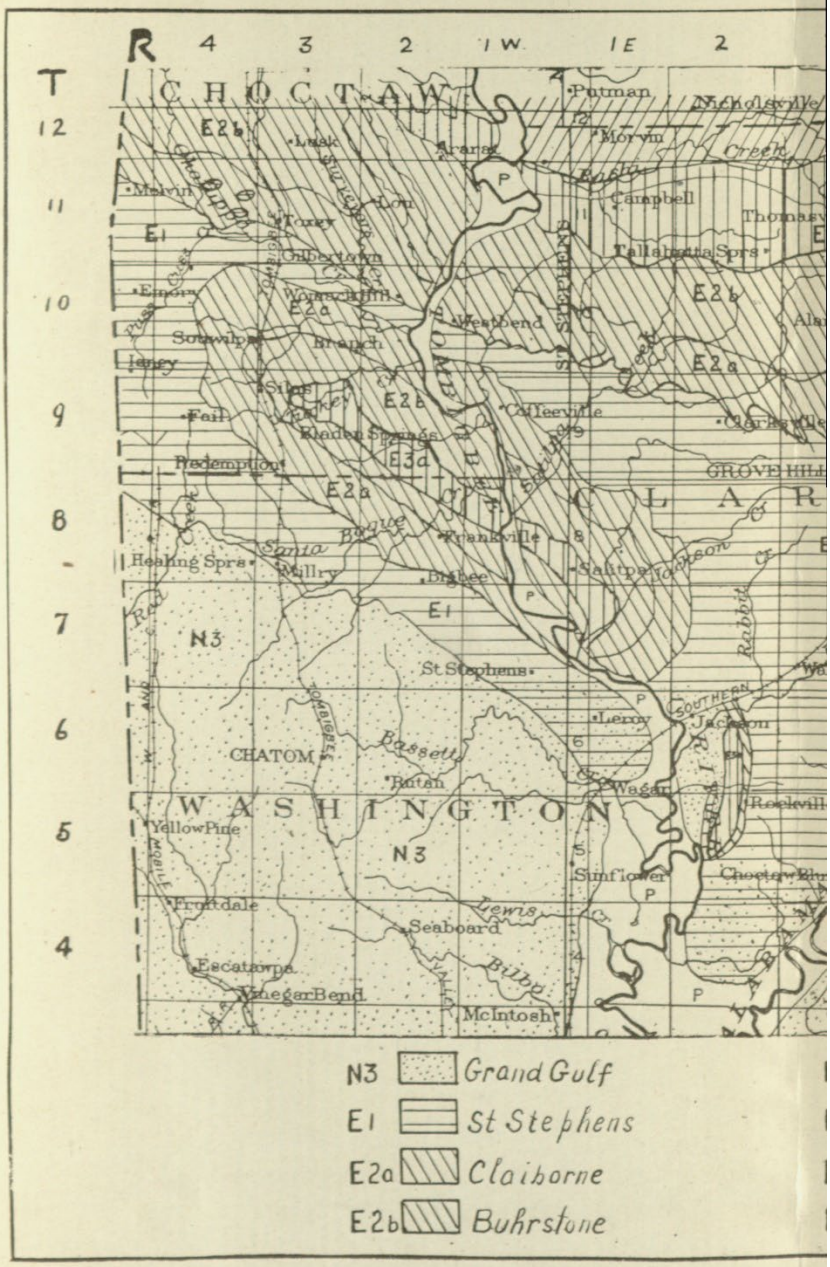
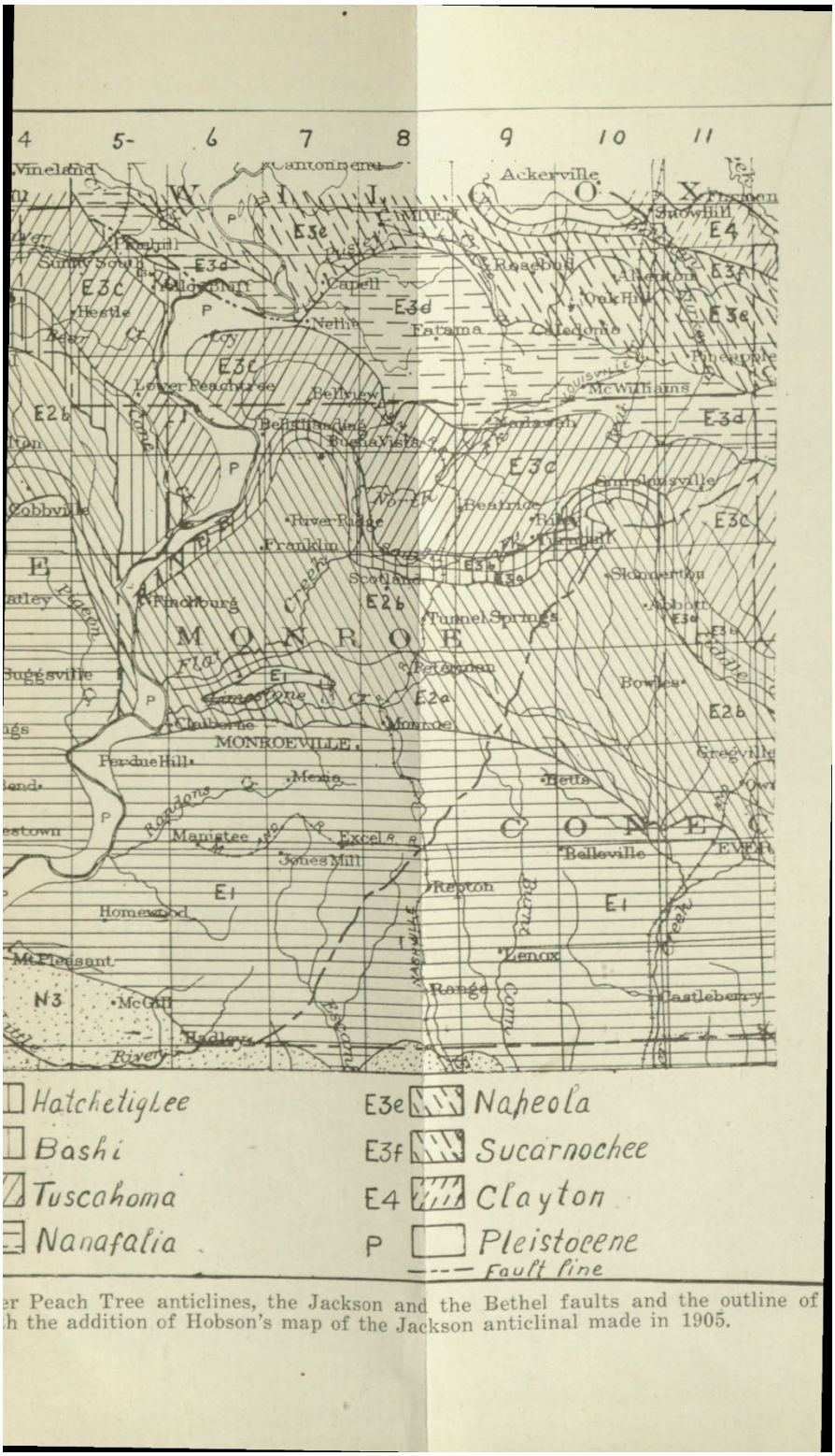


FIG. 25.—Geological map of part of Alabama, including the Hatchetigbee a
Beatrice fold. Copied from E. A. Smith's geological map of 1



er Peach Tree anticlines, the Jackson and the Bethel faults and the outline of
h the addition of Hobson's map of the Jackson anticlinal made in 1905.

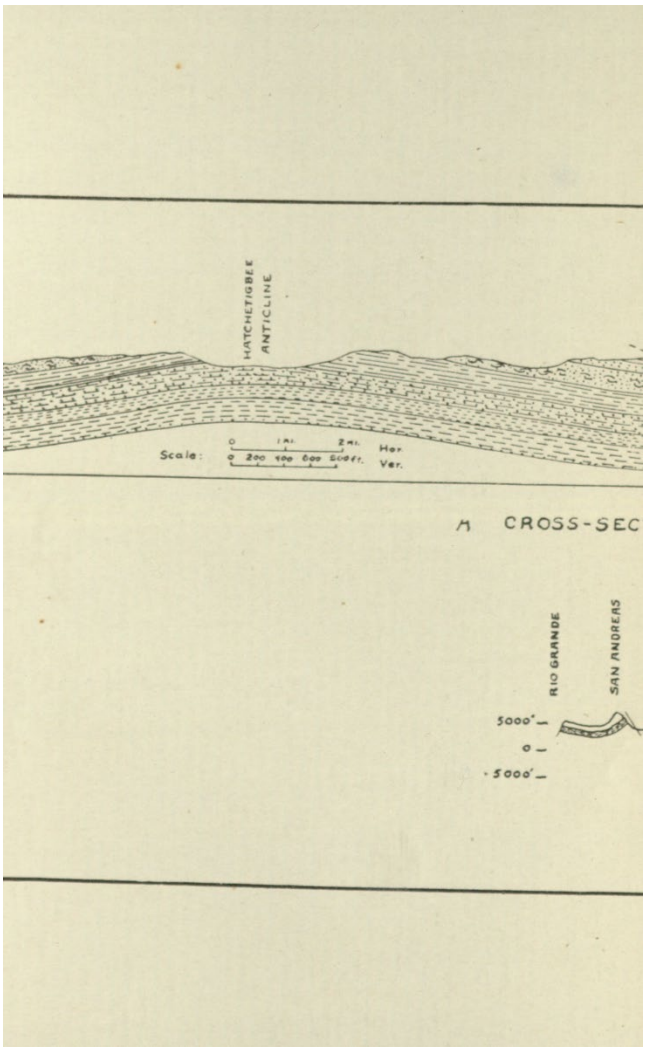
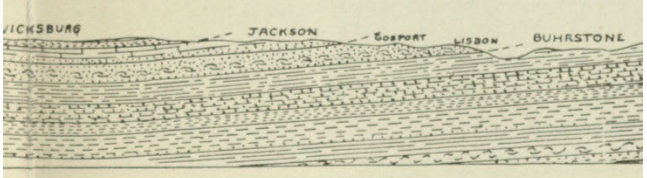
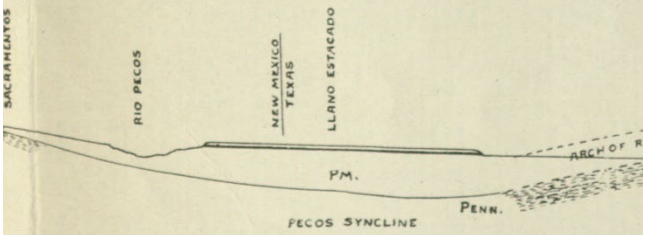

HATCHETIGBEE
ANTICLINE
Scale:
0 1 Mi. 2 Mi. Hor.
0 200 400 600 5000 ft. Ver.
A CROSS-SEC
RIO GRANDE
SAN ANDREAS
5000'
0
-5000'

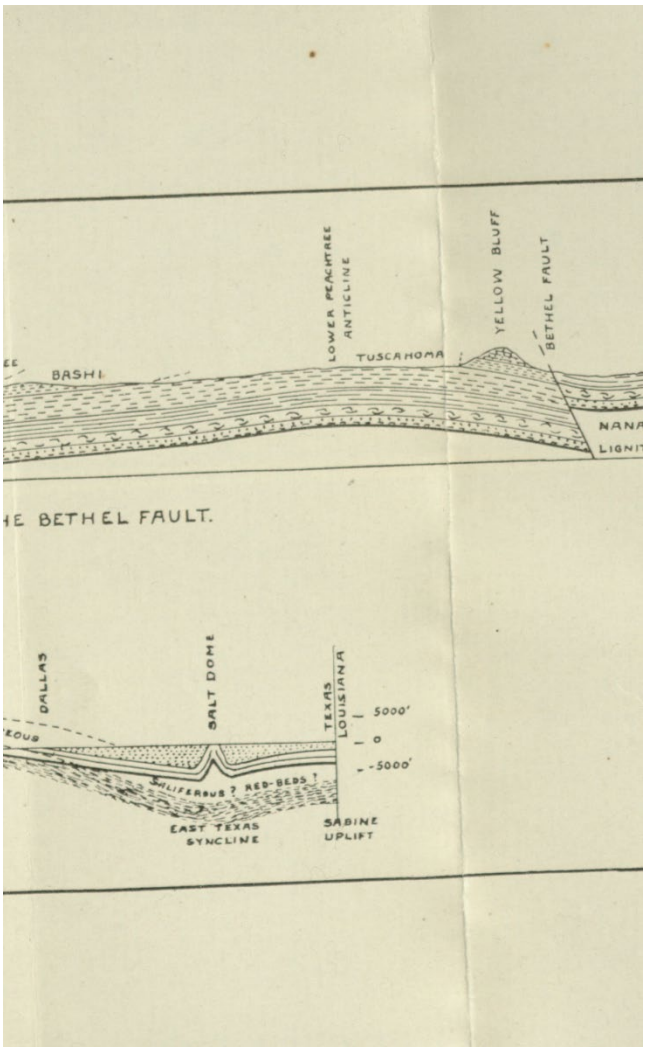
FIGURE 26



OF THE HATCHETIGBEE AND LOWER PEACHTREE

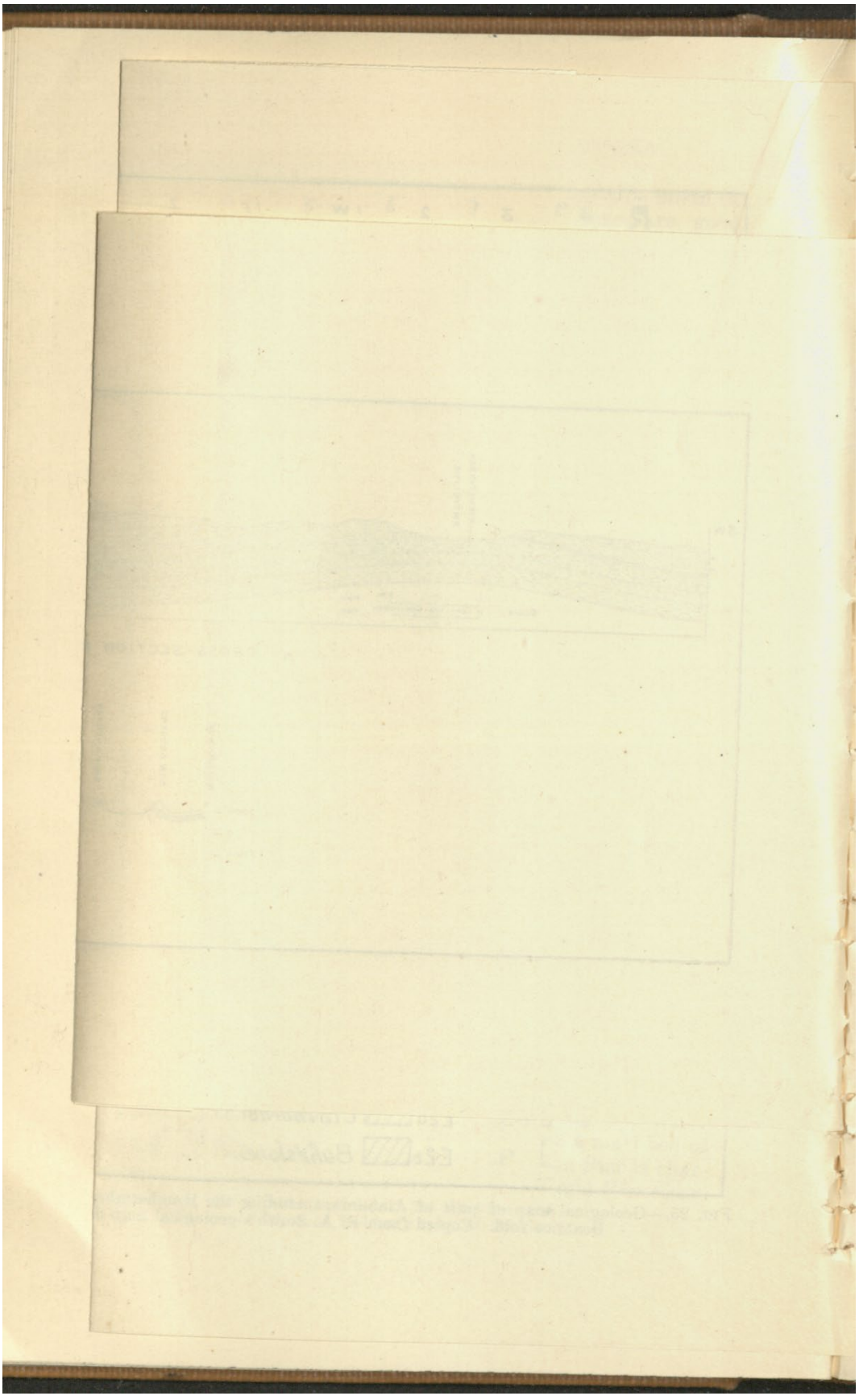


B. CROSS-SECTION THROUGH NEW MEXICO AND



HE BETHEL FAULT.

BLACK BLUFF
GULLETT BLUFF
NE
River
Level



dia planicosta. This same bed is exposed at Lower Peachtree Bluff four miles south of Yellow Bluff at an elevation of about 100 feet above the river level. Continuing downstream in a southeasterly direction the same fossil horizon is again seen at Bell's Landing, eight miles below Lower Peachtree, at an elevation of forty feet above the water. At this point the river bends to the southwest, crossing the west side of the anticline. About a mile further downstream to the southwest the marl bed passes below the surface of the water. From Lower Peachtree upstream to Yellow Bluff there are practically continuous exposures that allow the reading of dips which average between thirty and forty feet per mile. At Yellow Bluff the marl beds at a rate of fifty feet per mile from the lower to the upper end of the bluff. One mile upstream, east, a low bluff exposes the lower beds of the Bashi formation which are 70 feet above the Lower Peachtree marl bed of the Tuscahoma. This exposure is against the fault plane of the Bethel fault which will be mentioned later. Thus the position of the marl bed in Lower Peachtree Bluff is 170 feet higher than the same marl bed on the south side of the Bethel Fault, four and one-half miles northeast. Overlying the Tuscahoma formation at Yellow Bluff the Bashi formation is exposed in complete section, above which the lower 100 feet of the Hatchetigbee beds may be seen. See description of the Yellow Bluff section. The next exposures of Bashi and Hatchetigbee strata are at Davis' Ferry, six miles downstream from Bell's Landing.

No attempt has been made to trace the Lower Peachtree Anticline east of the Alabama River but it probably does not extend further than the middle of Range 7 west, where a slight syncline is present, apparently lying between the above anticline and the Beatrice fold. Westward of the Alabama River no definite evidence of the continuation of the Lower Peachtree Anticline has been recorded, but from the width of the outcrop of the Tuscahoma formation in northern Clarke and southern Marengo Counties considered along with the thickness of the formation and the normal dip, the possibility of the structure extending for some distance northwestward presents itself. The width of the outcrop in this area is about fifteen miles, while the normal dip is not less than 30 feet per mile and the thickness of the formation probably little over 200 feet. Therefore, it seems

that there has been at least a flattening if not an actual folding of the strata. There is also the possibility of a structural terrace or fold not connected with the Lower Peachtree Anticline.

The Bethel Fault (see Figures 25 and 26), so named by Smith from its occurrence near Bethel, in western Wilcox County, has a direction parallel to the axis of the Lower Peachtree Anticline, about N. 30° W., and limits the structure on the northeast side. There seems to be a very close relationship between the formation of the two structural features, they probably having been formed contemporaneously by the same tectonic force which acted in a direction normal to their axes. The fault plane is exposed in a low bluff on the Alabama River, one mile upstream and east of the upper end of Yellow Bluff, where it is seen to dip at an angle of near fifty-five degrees to the northeast. An unusual feature of the fault is that on the upthrow side, northeast, the strata dip away from the fault plane while on the downthrow side, southwest, the beds dip toward the fault. This is just the opposite to the structure of the normal fault, while it is difficult to conceive of a reverse fault movement in strata of this character with no more deformation of the beds in immediate contact with the fault plane than is shown in the exposure. The actual plane of the fault is clean and smooth while the strata in contact with it dip to the northeast at the rate of eight percent on the downthrow side and six percent on the upthrow side. This rather steep dip obtains for only a short distance on either side where it merges into the regular reverse dip of the Lower Peachtree Anticline. Northeast of the Bethel Fault the northeast dip continues for three-fourths of a mile making a reversal of seventy feet, which, added to that of the anticline, makes a total reversal of 240 feet.

On the northeast side of the fault the *Gryphaea thirsae* marl of the Nanafalia formation is exposed for six feet above the water, being overlain by the kaolin-like clay of the upper half of the Gullette Bluff beds. On the southwest or downthrow side beds twenty feet above the base of the Bashi formation are in immediate contact with the marl. Below this bed of the Bashi there are twenty feet of this formation, 150 to 160 feet of Tuscahoma strata and about 100 feet of Gullette Bluff beds above the marl. Therefore, the bed in contact with the Gryphaea marl on the opposite side

of the fault plane is about 270 feet stratigraphically above the marl, which shows a vertical displacement of that distance. Dr. Smith traced the fault from west of Bethel, where he found the displacement to be about 150 feet, to Section 24, Township 11 N., Range 6 E., east of the river, where he determined the throw to be near 300 feet. East of this locality the fault lessens rapidly in intensity and apparently ceases near Nellie. This eastern limit of the fault seems to conform with the eastern limit of the anticline, and it is probable that the fault extends as far to the westward as the fold.

The Lower Peachtree Anticline, as known at the present time has an axial direction of N. 30° E., extending from near Tinela, Monroe County, through the village of Lower Peachtree and on northwestward for at least ten miles. The width of the fold is nearly 8 miles while the maximum reversal is between 170 and 200 feet without considering the northeast dip on the upthrow side of the fault which adds 70 feet in a distance of less than one mile. The length of the Bethel Fault is probably the same as that of the fold, about fifteen miles, with a maximum throw of probably as much as 300 feet. There are dips on either side of the fault which are the reverse of the normal dip of the Alabama Coastal Plain. If the folding movement conforms to the fault displacement the highest point of the anticline is probably two or three miles southeast from Lower Peachtree, along the axis of the structure. However, in order to closely determine the area of the structure having the best possibility of yielding petroleum, a much closer study is necessary than those from which the writer has data. Another area worthy of very close study and consideration is the reverse dip on the northeast side of the fault. This fault plane at depth possibly offers a good channel for migration of petroleum from the deeper beds while it should be prevented from moving further upward than the base of the Selma Chalk, which, because of the nature of the material, should act as a sealing medium throughout its 1,000 feet thickness along the fault plane.

The Beaver Creek Anticline named for the creek of that name, which is just north of the fold, was observed at two points in the central part of Marengo County. At Nolan's Store in Section 23, Township 14 N., Range 1 E., beds of the Coal Bluff phase of the Nanafalia formation are exposed in

the road cuts for a distance of somewhat more than one-fourth mile. Northward from this belt of Coal Bluff beds the Gullette Bluff strata compose the surface over a strip of country about two miles wide. In the south scarp of the branch below Nolan's Store Gullette Bluff beds are again exposed. Thus we find a narrow strip of Coal Bluff beds as an inlier in the higher strata of the Nanafalia formation. This is not entirely due to the presence of a fold for the stream mentioned above has cut through the upper beds and into the lower but this does not entirely account for the occurrence. Where the contact of the Coal Bluff and the Gullette Bluff beds was seen in the road northeast of the store, the bedding planes have a dip of two to three percent to the northeast and north of this the hard ledges of the upper part of the Nanafalia beds seem to be near horizontal for a distance of a half mile. In the road cut in front of Nolan's Store the Coal Bluff beds dip at the rate of five percent to the northeast. Across the creek to the south the strata have resumed their normal direction of dip but at a rate considerably greater than normal.

In Section 36, Township 14 N., Range 1 E., on the Linden-Sweetwater road, the contact of the Coal Bluff and Gullette Bluff beds has a northeast dip of three percent while one-fourth mile northeast of this point the lignite bed near the base of the Coal Bluff dips four feet in five hundred in the same direction. One-half mile north of this point the normal southwest dip was observed in the same lignite bed. On a steep hill on the road in the south part of the section the upper beds of the Nanafalia have a dip of probably two percent to the northeast. Immediately south of this point no exposures were seen but it is assumed from the outcrops further southward that the normal dip obtains. No other investigations were undertaken in this area so it is impossible at this time to do more than mention the two points at which cross-sections of an anticline were made and the possible connection between the two. The cross-section made at Nolan's Store is about twenty degree north of west from the section northeast of Sweetwater, which, though not the usual direction of the axes of the structures of southern Alabama it is sufficiently near to assume that the two cross-sections are on the same fold. The northwestern end is hardly as much as a mile wide while the reverse dip where seen northeast of Sweetwater is at least a mile in length.

We assume then that there is in that portion of Marengo County immediately south of Beaver Creek a small anticline having an axis trending N. 70° W. To the southeast from Nolan's Store the fold increases in size at least to the Linden-Sweetwater road, two to three miles north of Sweetwater. There remains the possibility that southeast of this last mentioned locality the structure becomes more extensive than yet seen.

Hatchetigbee Anticline (Figures 25 and 26).—The great fold in the Tertiary strata in southwestern Alabama was first studied and mapped by Smith and Langdon* and named "Hatchetigbee Anticline" for the formation of that name that has been exposed along the axis of the structure by the erosion of the younger formations which overly the Hatchetigbee formation. Later Hopkins† described and mapped the area of the structure and discussed the possibility of the occurrence of petroleum. In this report the description is largely a summary of the work of Smith and Langdon.

The Hatchetigbee Anticline extends from near the central part of Clarke County through the northern part of Washington and into Choctaw County to near the Mississippi line, having an axial direction of N. 55° to 60° W. The length of the structure as marked by the exposure by erosion of older formations than those that would normally cover the area is about 35 miles, while the maximum extent of the area affected is considerably more, probably 50 to 60 miles. The width of the fold from the trough of the syncline on the northeast to the point of equal stratigraphic elevation to the southwest is from 15 to 18 miles.

As mentioned above, the Hatchetigbee formation is exposed along the crest of the fold as an inlier for a distance of 20 miles while other formations lying stratigraphically above the Hatchetigbee likewise outcrop as inliers and encircle the highest part of the fold in the following order: Tallahatta, Lisbon, Gosport and Jackson formations. The Vicksburg is the normal formation of the area and it is within that terrane that the structure was formed. About fifteen miles northeast of the Hatchetigbee inlier that formations reaches the surface in its proper position as a mem-

*Smith, Eugene A., and Langdon, D. W. Geology of the Coastal Plain of Alabama, Alabama Geological Survey, 1894.

†Hopkins, Oliver B. Oil and Gas Possibilities of the Hatchetigbee Anticline Alabama, U. S. G. S., Bull. 661-H, 1917.

ber of the series of formations which compose the Coastal Plain monocline. Considering a dip of thirty feet per mile to the southwest as normal for this part of the monocline the Hatchetigbee beds exposed along the axis of the fold are at least 450 feet above the monoclinal position. According to Hopkins the axis of the structure is higher near Salitpa and Bladon Springs than the general level, while there is a saddle from Section 22 to Section 8, Township 8 N., Range 1 W. The southeastern end of the structure ends suddenly against the Jackson fault while the folding was probably effective northwestward into Mississippi. If the thickness of the formations below the surface of the folded area was the same as along their outcrops to the north, the top of the Selma Chalk would be encountered at from 1,200 to 1,250 feet below the surface, but from the log of the Mitchell No. 1, drilled in Section 26, Township 8 N., Range 1 W., the chalk was found at 1,700 feet below the surface. This shows a greater thickness by 400 feet than the sum of the thicknesses of the formation penetrated along their outcrops, The Selma Chalk shows a thickness of 950 feet, which is about the same as the thickness given by well logs and the surface outcrop up the dip from the well. In the Bollinger No. 1, Section 13, Township 9 N., Range 3 W., the chalk was entered at 1,980 feet. In the Cullom Springs well near Bladon Springs the Selma was encountered at 1,220 feet, according to Langdon,* who was on the ground at that time. This is about the calculated depth for the chalk. If the logs are correct the Cullom Springs well is on the calculated structural high while the other two wells cited are on low parts of the folds that, according to the surface data, should be as high as at Bladon Springs.

The area of the *Jackson Fault* was first worked over by Smith, who explained the abnormal position of the formations exposed due to a north and south fault or a steeply folded anticline. Later Hobson studied the area for the State Survey and considered that an anticline with a north and south axis was present. Hopkins‡ has made a more recent investigation and is of the opinion that a fault having a throw of 300 feet near its northern and at least 450 feet near its southern extremity extends from Section 12, Township 7 N., Range 1 E., southeast to a point two miles

*Op. cit.
‡Op. cit.

east of Jackson Station, where it bends southward to the Central Salt Works and thence southwest to and possibly across the Tombigbee River at the Lower Salt Works. No actual fault plane has been seen by any of the investigators but the relative positions of the several formations concerned in the surface of the area seem to preclude the possibility of accounting for the abnormalities by other than faulting. Both Smith and Hopkins found north of Jackson, Vicksburg or Orbitoidal White Limestone on the southwest side of a northwest-southeast line and Jackson limestone and Claiborne strata at about the same elevation on the northeast side of the line. South of Jackson, beds of Hatchetigbee age are exposed to the eastward in almost direct contact with Vicksburg limestone to the west. Hence the down throw side seems to be to the west and southwest of the fault zone. The strata on the west or down throw side of the fault dip toward the plane of displacement, according to Hopkins, while those on the east or upthrow side dip at the rate of two percent to four per cent away from the fault or to the east and northeast. It is a notable fact that the dip of the strata concerned in the Jackson fault bear the same relation to the fault plane as do the beds on either side of the Bethel Fault in Wilcox County.

The strata dipping northeast along the upper limb of the fault north of Jackson are in almost the reverse position to the normal direction of dip in this area of the Coastal Plain and therefore should act as a trap for the retention of any petroleum which might have migrated along the fault plane, provided it did not escape to the surface, and also that which might have migrated normally up the dip of the strata. This is an area that is suggestive of the possibility of the presence of petroleum in commercial quantities, other conditions being favorable. The area as mapped by Hobson is shown on the geological map of the Hatchetigbee Anticline accompanying this report, on which the probable fault is shown as an anticline.

The Beatrice Anticline (Fig. 25).—A deformation of the Coastal Plain strata from their normal position in northern Monroe County, Ranges 7 and 9 East, Townships 8, 9 and 10 North, is tentatively designated as the Beatrice Anticline. From a glance at the geological map of the area it is readily seen that the unusual trend of the several formations concerned suggests the possibility of some structural

movement having caused the wide deviation from the normal position and direction of the outcrop of the beds. In attempting to check this apparent condition the writer used the base of the Tallahatta Buhrstone as the key horizon. Beginning on the Alabama River west of Franklin a ridge of Tallahatta Buhrstone with Hatchetigbee beds along the base extends northeast to near the Wilcox County line, a distance of ten miles, where it bends sharply to the south, continuing for eight miles to the southwest corner of Township 9 N., Range 8 E. From this point the ridge trends slightly south of east for eight miles, where it bends northeast to the north central part of Township 9 N., Range 10 E. Here the scarp turns southeast to Sepulga, Conecuh County. An excellent exposure of the contact of the Tallahatta and Hatchetigbee formations may be seen in the cut at the north mouth of the Louisville and Nashville Railroad tunnel in the northwest corner of Section 13, Township 8 N., Range 8 E., while the approximate and actual contact of the two formations can be traced along the scarp outlined above. By running aneroid barometer levels the key horizon was found to be about 100 feet lower on Flat Creek, eight miles slightly north of west of the tunnel, than at the latter point. Ten miles northeast of the tunnel the contact has an elevation of 40 feet lower than at the key locality. In the railroad cut north of the tunnel the beds show a dip of two per cent, S. 45° W. Considering the axis of an anticline or nose to lie a short distance west of the tunnel we find that the strata dip west and southwest and east and southeast from it. From the position of the Tallahatta at Tunnel Springs, three miles south, a sharp south dip obtains south from the tunnel. No data further than give above were secured in this area or northward in Wilcox County, except in the Grampian Hills immediately south of Camden. Here the Nanafalia beds were found to be flat with a possible very slight northward dip for a distance of a mile or more along the Camden-Fatama Road, some two to four miles southeast of Camden. At Vredenburg the base of the Nanafalia was found in a well at a depth of 200 feet. This should be in the trough to the west of the supposed structure and between it and the Lower Peachtree Anticline. The sharp northwest bend in the Alabama River at Bridgeport suggests the possibility of structural influence while the Ripley marls outcropping along this northwest reach of the river

show some northwest dips which seem to be local but may have some connection with a more considerable movement to the southeast. Granting the presence of an anticline or monoclinal nose in Wilcox and Monroe Counties, the axis of the fold is most likely about N. 15° to 20° W. This area was very hurriedly covered and the study was only sufficient to indicate the advisability of a more thorough investigation of its possible relation to the accumulation of petroleum.

Other Areas of Possible Folding in Southern Alabama.—geological map of southern Alabama shows an area in which the trend of outcrop of the formations makes a wide swing to the southward in southern Butler and eastern Monroe Counties, similar in map appearance to the position of outcrop around the Beatrice Anticline to the west. The area which seems to be worth investigation lies between Commerce, Garland, Shell and Butler Springs on the west, south, east and north, respectively. A swing to the south of the formations between Red Level and Evergreen, together with the unusual width of the terrane of the Buhrstone outcrop suggests the possibility of folding or structural terraces possibly connected with the area to the northwest mentioned above. This southward swing may have been occasioned by the erosion effected by streams which flow southward through the areas but considering the comparatively slight relief and the very considerable southward displacement of the formation outcrop it does not seem likely that erosion alone accounts for the variation from the normal.

In Monroe and Conecuh Counties, south of Monroeville, the considerable width of the outcrop of the St. Stephens Group limestones suggests the possibility of small folds in the strata or the presence of structural terraces. There are likewise other localities in the Coastal where the possibility of folds or flattenings in the strata is suggested by the width and position of outccrops. In fact the monoclinal dip of the Coastal Plain formations is so comparatively slight that small folds or terraces might have been developed in almost any area without its being evident except through rather close and detailed study. A slight northeast or reverse dip shows in the Southern Railroad but a few miles north of Livingston, Sumter County, but it is not considered that the subsurface conditions in this area are particularly encouraging.

SALT DOMES.

West of the Mississippi River there are two groups of Salt domes, one of which occurs in the near coast strip where the surface formations are post-Miocene and the other group further inland, generally known as the "interior salt domes," where the surface formations are of Eocene age. In Texas and Louisiana the post-Miocene strata consist of some 4,000 feet of strata, while in Alabama beds of this age are only a few hundred feet in thickness. Hence we have in the latter state no conditions which are identical with those of the coastal salt dome area of Texas and Louisiana. Eocene and Upper Cretaceous formations of the interior salt dome region of Texas and Louisiana are practically identical with the same group in Alabama from which we might consider that in Alabama we have, above the base of the Upper Cretaceous, conditions similar to those in Texas, except that East Texas is synclinal while southern Alabama is monoclinal. The following article on salt domes has been kindly prepared by Mr. Robert T. Hill for use in this report:

Salt Domes.

"In Texas and Louisiana there are peculiar geologic features with which oil is sometimes associated, known as salt domes. It is not always easy to determine the presence of these domes. They may occur as slight domical topographic elevations above the adjacent physiography, or as depression below the general surface. The area occupied by them and the disturbed strata surrounding them is small, seldom exceeding a mile or more in diameter.

Knowledge of the salt domes is comparatively new to science and they were practically undiscovered until the persistent explorations and operations of Captain A. F. Lucas in the salt and oil fields in central Louisiana and Texas in 1900-1902, made them known to the world. Although Lucas' discoveries and ideas were not at that time formulated in words, he first discovered the domical nature of the domes and demonstrated a deep salt core, the arching of the strata around them and the association of oil with them. The writer, in 1902, published an account of Captain Lucas' operations and results with his approval.*

These domes and their surroundings occur as vertical salt columns, sub-cylindrical in cross-section, which penetrate the Cretaceous, Tertiary and Quaternary strata from below. The upper end seldom appears at the immediate surface, sometimes having been dissolved away and covered with debris, and at other overlapped by the later strata which they have partially penetrated. The surrounding strata are flexed upward, around and over the upper end of the column of rock salt and correspondingly dip sharply away from them in every

*"The Beaumont Oil Field with Notes on Other Oil Fields in the Texas Region." Journal of the Franklin Institute, Philadelphia, an institute of Mining Engineers. New York, 1902.

direction. The downward extent of the salt column in unknown. In Louisiana, as at Belle Isle, they were drilled into to a depth of 3,000 feet by Captain A. F. Lucas.

The domes may be classified by location into two categories, as follows: (1) The salt domes of the Coastal belt, in which area the surface formations consist of nearly 4,000 feet of post-Miocene strata; and (2) salt domes of the interior, in which the surface formations are mostly Eocene, from Wilcox to Jackson, inclusive. The age of the Coast Domes is placed by both Wm. Kennedy§ and E. T. Dumble* as late Tertiary.

Dumble more definitely states it as "post-Lafayette-pre-Port Hudson," which is practically the late Pliocene or early Pleistocene.

According to Powers and others, the interior domes and the Coastal domes are of different ages.** Hopkins*** concluded that the East Texas domes were probably uplifted before the deposition of the Midway. Powers¶ fixes the uplift of the Butler dome as toward the close of the Midway.

Origin of the Domes.

Several theories have been advanced as to the origin of the domes which may be termed the hydrostatic, the tectonic, the "diapir" and the volcanic. The latter, which infers that the domes are indefinitely connected with sites of former volcanic activity and associated in origin with them, is too hypothetical for consideration and as the alleged data upon which this hypothesis is usually founded are fallacious, we do not think the theory worthy of consideration.

The hydrostatic theory originally advanced by the author in 1902, attributed the origin of the salt columns to the ascension and subsequent condensation of the salt in solution along lines of fissures. He gave no satisfactory explanation of the doming of the strata, nor did he realize then how extensively they were arched.

The tectonic theory holds primarily that the salt of older formations has been brought nearer the surface along the axis of anticlinal folds.†

The "diapir" theory propounded by Mrazec‡ is the tectonic theory plus one which holds that the salt has been bodily pushed up into and through the folds of strata in a semi-plastic condition. There are several supporting factors to the tectonic theory, the chief of which is the existence of structural conditions confirmatory of such a theory supported by the probable fact that rock salt may occur in the underlying rocks.

Inasmuch as the Mississippi embayment and Gulf of Mexico compose a deep synclinorium eastward of a former central Texas highland, the algebraic sum of the movement producing this condition has been subsidence in the embayment, accompanied by parallel step fault zones and folds of the Balcones and Mexico type.

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§Bull. Southwestern Association of Petroleum Geologists. Vol. 1, p. 51, 1917.

*Origin of the Texas Domes, Amer. Inst. Min. Engrs. Bull. 143, p. 1635, 1918.

**American Journal of Science, Feb., 1920, pp. 149-150.

***U. S. Geol. Survey. Bulletin 661, p. 263.

¶Op. cit., p. 139.

†See Origin of the Texas Domes, by E. T. Dumble, Amer. Inst. Min. Engrs. Bull. 143, 1918.

‡Les plis a noyaux de percement, Bulletin Scientific Society of Bucarest, 1906.

Source of the Salt.

There is much speculation as to the origin of the salt in these domes. The occurrence of this salt, before its columnar nature was known, was theoretically considered by G. D. Harris as land locked lagoonal deposits, evaporated from the margins of the Cretaceous seas. Later the writer* assumed that these salt occurrences were not native to the strata in which they were found but were ascensional as hot saline solutions from still lower strata, and therefore of secondary origin. Waters now arise from fissures of this type known as the Balcones fault zone, and there is no reason why waters should not have arisen in the past through similar and parallel fissures to the east. Saline waters with increasing temperature with depths, also arise from deep wells at Marlin and elsewhere. The writer also held the salt and oil were contemporary in origin, but this hypothesis is no longer tenable for the salt column is now often known to penetrate beds in which the oil occurs.

Dumble** has recently expressed the opinion that "the salt of the Cretaceous (inland) domes probably has its origin in the evaporation of sea water in shallow basins during the period of Comanchean sedimentation or Mid-Cretaceous interval."

While it is true that gypsum, an accessory mineral to the salt, is found in basement littoral of the Comanche Cretaceous in Southern Arkansas, and which are of semi-continental nature and possibly the top of a series of lower "Red Beds," the writer is inclined, for reasons which will be presently be set forth, to consider that the original or mother source of the salt in the columns of the domes may have been in still lower strata.

Our reasons for this hypothesis are as follows: The Comanchean Cretaceous, which has been drilled into around these domes in several places in East Texas and Louisiana, so far as known, has the same deformation as that of the overlying strata and were therefore similarly penetrated by the salt column. Furthermore none of the wells drilled into the Comanchean Cretaceous, in East Texas and Louisiana has encountered bodies of salt or strata of appreciably saline nature. The source of this salt must, therefore, be probably more deeply seated than the Comanchean Cretaceous.

The Pre-Comanchean Floor.

Definite knowledge is lacking as to the age and nature of the rocks below the Comanchean Cretaceous floor in East Texas. It has been generally supposed that these overlying strata were of Pennsylvania age, but data recently obtained from widely separated localities, indicate the extensive occurrence there of "Red Beds"—like continental formations instead. If these Red Beds are the same as those which overlie the Pennsylvanian in West Texas (and there is no reason for supposing that they are not the same), and contain similar vast beds of rock salt, then it is not difficult to estimate the most probable source of the latter material beneath the Comanchean Cretaceous in East Texas.

There are good reasons for suspecting that the semi-continental Permian Red Beds of Western Texas with their great salt beds may extend beneath East Texas and Louisiana. These beds now occupy a great regional syncline in West Texas. This syncline passes on the east into a broad anticline, the arch of which is supposed to be

*Journal Franklin Institute, August-October, 1902.
**Univ. Texas Bulletin No. 1869, 1918, p. 308.

approximately beneath Fort Worth. From thence eastward another great syncline begins beneath the Mississippi embayment.

The summit of the Fort Worth Arch was truncated in Triassic or Jurassic time by pre-Cretaceous peneplanation and the Red Beds of Permian and later age, which, with the Pennsylvanian strata, composed it, were eroded away from the North Central Texas district. There is no logical reason for presuming, however, that the Red Beds were not preserved in the East Texas Syncline as well as that of West Texas. The salt of the salt domes in our opinion is contributory evidence to this hypothesis. (See Figure 26.)

According to Rogers* "the derivation of the European salt domes from a Permian bedded deposit now appears to be indisputable." It is very probable that similar conditions may yet be proven beneath the East Texas and Louisiana regions.

The Problem of Ascension.

Two hypotheses have been advanced dealing with the method of the ascension of the salt. One of these is by Mrazec,† a Bohemian are cited by Powers in the American Journal of Science, February, 1920, p. 140, and Rogers in American Economic Geology, Sept., 1918, pp. 466-467.

The first of these hypotheses would account for the disturbance of the adjacent strata, as will be presently further explained. The latter is supported by modern instances of the ascension of hot saline solutions seen in many deep wells. The crustification in the massive salt columns as seen in the deep shafts of the salt mines of Louisiana, is contributory testimony indicating that the salt of the domes may have ascended in solution. Three hypotheses have been advanced for the pushing up of the strata above and around the domes. One of these presumed that the softer and less consolidated upper strata have subsided around the top of the salt column. This is now known to be untenable. A second, propounded by G. D. Harris, implied that the doming had been caused by the expansion accompanying the crystallization of the salt from solution. The third theory, now much in favor, is that of Mrazec that the salt in a semi-plastic condition was pushed up through fissures as an extension of a great stratum of salt below and which, as he alleges, was the case with the salt formations along the south front of the Carpathians in Roumania which have been extensively studied by him. There, as in Texas, the salt column and some of its surrounding strata penetrate upward through the later beds as much as 7,000 feet at certain points on structural axes, originating a structure very much like our Texas domes, but more oblong in outline and occurring at certain points along definite anticlines. Perhaps it is to his conclusions that we may best look for the most plausible explanation of the Texas deposits, but with some as yet undetermined modification. This hypothesis of Mrazec's may be true, but like some obscurely propounded occult doctrine, it requires much further reflection before acceptance.

Notwithstanding the rapidly accumulating literature of the subject, the time is not as yet ripe for final deductions, and, as stated by Powers, "it is to be hoped that a careful digest and analysis of the

*Economic Geology, Sept., 1918, p. 466.

†In various Roumanian publications, the principal ones of which geologist, who postulated that the salt may have been pushed up the fissures in a semi-plastic condition resulting from pressure. The second hypothesis is that the salt rose in supersaturated solution through hydrostatic pressure.

hosts of unpublished information about salt domes will be forthcoming."‡

Oil in the Salt Domes.

It is a peculiar incident that oil has thus far been found only in the 4,000 feet of Plio-Pleistocene strata around and over the salt domes of the Coastal belt. The few tests around the interior domes of Texas and Louisiana, which penetrated the Woodbine and other Cretaceous sands, have proven barren with the exception of a few quarts of oil, found in one locality, such as might be found in the same strata at any other locality away from the domes.

The tests of the interior domes have been relatively few and unproductive but insufficient in number to condemn them. As stated by De Golyer,** "these tests prove nothing but the barrenness of the limited area on which they were drilled. Many of the salt domes of the Coastal Group had been prospected intermittently for years before production was found." Some of the Coastal domes like those of West Columbia, Damon and Goose Creek have required from 15 to 18 years experimentation before coming into production."

In the foregoing article by Mr. Hill, he presents the theory that the salt of the domes has been derived from beds below the Cretaceous in Texas and Louisiana, most likely the Permian. Accepting this theory, we have a plausible explanation of the seeming absence of salt domes east of the Mississippi River. There is no known occurrence of Permian in the southeastern states overlying either the Pennsylvanian or the older pre-Cambrian crystallines. On the other hand, the most recent pre-Cretaceous beds are of early Pennsylvanian age while from the dip of the Cretaceous sea floor of older crystalline rocks, it is quite evident that the land area of pre-Cambrian rocks was much greater during Paleozoic times than at present. By projecting the present contact of the Paleozoic pre-Cambrian we find that it will extend southwestward to the present delta of the Mississippi River, east of which no salt domes are known. It is not known that the crystallines directly underly the Coastal Plain this far southwest but there is no data to disprove it. Thus we find salt domes in areas west of the Mississippi River where it is most reasonable to expect the presence of Permian below the Cretaceous and upon which there have been gathered recently, data that uphold the theory. East of the Mississippi River in the near Coast area the possible presence of Permian strata cannot be accounted for between the Lower Cretaceous and pre-Cambrian rocks.

‡American Journal of Science, February, 1920, p. 140.
**"The Journal of Geology," Nov.-Dec., 1919, p. 663.

To summarize: West of the Mississippi River, where the presence of Permian strata, which contain salt beds, is probable, there are numerous salt domes; east of the Mississippi River, where pre-Cambrian crystallines and Pennsylvanian rocks underly the Cretaceous, there are no salt domes. These conditions support the theory by Mr. Hill of the derivation of the salt from pre-Cretaceous beds and at the same time points to the unlikelihood of the presence of salt domes along the Eastern Gulf and Atlantic coasts.

POSSIBLE SANDS BENEATH THE COASTAL PLAIN.

The consideration of the sand horizons beneath the Coastal Plain of Alabama that might have possibilities of producing oil in commercial quantities is rather unsatisfactory, largely because of the lack of data concerning the subsurface formations over the areas that are considered to be the most promising. Several wells have been drilled in the extreme southern part of the State but none of them has been of sufficient depth to penetrate all of the strata within what is now considered to be the economical depth for thorough testing. On the Hatchetigbee Anticline two deep tests have been put down, one to 3,400 feet below the surface and the other to 4,013, which show all the strata from near the top of the Hatchetigbee formation through the Tuscaloosa, the lowest member of the Upper Cretaceous, and into what is probably the Comanchean, giving a fair idea of the subsurface beds in the southwestern portion of the State. East of the Alabama River few wells have been sunk to more than 1,000 feet and therefore throw little light on the situation. In the absence of these definite data it becomes necessary to study the areas of outcrop of the various formations and compare them with the areas similar formations from which petroleum is being obtained in commercial quantities in other states.

The Tuscaloosa Formation.—This formation, which is the lowermost of the Upper Cretaceous or Gulf Series, outcrops as unconsolidated and cross-bedded sands, vari-colored clays and gravels. For more complete descriptions see the chapter on the Tuscaloosa and Lower Cretaceous beds under Areal Geology. The nature of the materials of the deposits and the structure of the beds show that they were deposited as continental or delta deposits. Frequent clayey

portions of the formation contain abundant leaf impressions and some lignitic material which is evidence of the existence of a more or less luxuriant plant life. With the normal transitional sedimentation seaward or down the dip of the strata it would be expected that along the shore line of the Tuscaloosa sea there would be semi-marine or littoral deposits, succeeded in turn by predominating shales and clays and next calcareous materials. We are dependent on the logs of wells that have been drilled toward the present southern limit of the outcrop of the formation for information regarding the actually existing conditions.

The only wells that have penetrated strata that might be referable to the Tuscaloosa, except within a comparatively short distance of the outcrop, are the Bollinger No. 1, drilled by the Empire Gas and Fuel Co., in Section 13, Township 9 N., Range 3 W., on the Hatchetigbee Anticline northwest of Bladon Springs, Choctaw County and the Mitchell No. 1 in Clarke. The log of the former well is given on page 206. It will be noted that from the depth of 3,615 to the bottom of the well, 4,013 feet, all of the strata are logged as red "gumbo" or shale, except thin beds at the top and bottom of this portion of the vertical section. These strata occupy the stratigraphic position below the chalk of the Tuscaloosa but are here referred, because of the nature of the material, to the Comanchean or Lower Cretaceous which, if correct, shows that the Tuscaloosa has thinned considerably. Overlying the red beds there is a thickness of 460 feet of white and green sand that are considered to belong to the Tuscaloosa formation. The sand, shales and limestone from 2,790 to 3,176 are placed in the Eutaw formation and show from the formation outcrop a seaward transition from sands and marls to shales and limestone. These logs do not lend particular encouragement to the possibilities of the Hatchetigbee Anticline despite the fact that the structurally highest part of the fold has not been drilled below the Selma Chalk.

The Woodbine of Texas and Louisiana, which is productive in the latter state, is composed of littoral sands, clays and bituminous clays along its outcrops and largely of bituminous shales and clays with thin sand beds in the areas where it yields production. In these states red sands and clays have been found in some localities below the Woodbine horizon and in eastern Louisiana immediately below

the chalk horizon which in that section is correlated with the Annona of east Texas. Some relationship between these red materials west of the Mississippi River and those penetrated in the Bollinger No. 1 suggests itself but at the present time the evidence is too meager to draw conclusions.

The Eutaw Formation, which is the time equivalent of the lower portion of the Austin Chalk of Texas and probably a considerable part of the Eagle Ford formation, immediately underlies the chalk in Alabama. The Tombigbee sand member of western Alabama and Mississippi occupies the stratigraphic position of the Blossom sand of northeast Texas and Arkansas and is probably very near the time equivalent. Along its outcrop the Eutaw consists of shallow water marine sands, clays and marls while in its upper portion in central and eastern Alabama it becomes very calcareous. Down the dip of the strata the horizon becomes more shaly, as indicated by the logs of several wells south of its outcrop, and seems to be following the normal depositional transition with variations in the form of sand beds. In a well drilled three miles south of Myrtlewood, Marengo County the Eutaw horizon contains considerable chalk inter-stratified with sand. Southward to the Bollinger well the excessive thickness of the chalk may be accounted for by the transition of Eutaw sands into limestone. In that case the sands below the chalk and over the red beds are referable to the Tuscaloosa formation as suggested above.

The writer was present when the well near Myrtlewood was being tested for water and found it to produce on the pump five gallons per minute of salt water that seemed to be a 25 per cent or more saturated solution with considerable gas escaping from the hole. There was also a rainbow on the water, which the driller insisted came out of the well, but which might have been either from the pump or tools. A log of the well as reported by the driller with formational subdivisions is given on page 203. This log shows a 75-foot bed of blue shale that is the probable source of the little gas and possibly the oil if it actually comes from the well. The Blossom sand and containing horizon in Louisiana is composed of blue shales and clays with thin beds of sand carrying oil on some of the structures drilled.

The Selma Chalk is in its lower part equivalent in time of deposition as well as lithologic character to the Annona

chalk of Louisiana. This horizon is productive in the Caddo field in the latter state, and it is interesting to note that showings were found in the Selma Chalk in the Mitchell No. 1 well on the Hatchetigbee Anticline and a well drilled on the Jackson Anticline near Jackson, Miss. In Louisiana the Annona has most likely been made productive by migration from a lower horizon. It is unlikely that the phenomenon will be repeated in Alabama.

The Ripley Formation, which in eastern Alabama has a thickness of nearly 1,000 feet, occupying the entire Selma-Ripley horizon, thins to the westward and disappears in the vicinity of the Tombigbee River. In the Alabama River section it has a thickness of 270 feet and south of Union Springs it is composed of some 450 to 500 feet of the typical beds. The materials along the outcrop of the formation are clear quartz sands, glauconitic and black argillaceous sands, clays, shales and marls. In a few localities the marls are indurated and act as the supporting medium for a rather rugged topography. The outcrop is described more fully under formation descriptions. Except in the southwestern part of the State no wells of which we have record have been drilled into the Ripley strata at any considerable distance from the surface terrane of the formation so that we have no knowledge of the character of the materials down the dip from the outcrop, except as mentioned below. The strata exposed are of near shore marine deposition, and with the normal transition a zone of predominating shale should be expected at some distance from the old shore line and next, with favorable conditions of sedimentation, calcareous materials. Whether or not these shales, if present, are bituminous and contain sands that might act as containing mediums for any petroleum which might have originated in the shales can only be told by the drilling of test wells. Any remarks that might be made regarding the possibilities of the sands would only be hypothetical. In the area of the Hatchetigbee Anticline where the only deep tests in southern Alabama have been made, the Ripley is missing or is present as shales and "gumbo" as shown by the Bollinger No. 1, and the Mitchell No. 1, the logs of which are given.

The Ripley is the stratigraphic and time equivalent of the Navarro formation of Texas which is, in turn, the depositional equivalent of the Arkadelphia clay of Arkansas. This latter formation contains the Nacatoch sand, one of

the productive horizons of northern Louisiana. Along its outcrop the Ripley is quite similar in lithologic character to the Navarro, they both being near shore marine deposits. Away from the outcrop of the Navarro the sediments change to predominating shales and clays similar to the exposed beds of the Arkadelphia. The logs of practically all the wells which have penetrated these formations away from their outcrops show the fine sediments to be black in color. No well data are available in Alabama by which an idea of the character of the Ripley down the dip from the surface terrane can be obtained.

From the character of the Ripley surface materials, their stratigraphic position and their thickness in the central and eastern parts of the State, it seems that the Ripley sands have probably the most promising outlook for the production of petroleum in commercial quantities of any of the strata which compose the Coastal Plains sediments in Alabama. As yet no showings or gas have been found in this horizon but at the same time no wells are known to have penetrated the beds and probably have not except as above mentioned.

The *Tertiary strata* have been penetrated in quite a number of localities in the southern part of the Coastal Plain with showings of oil and a little gas reported in a few wells. On the Hatchetigbee Anticline and near by several wells that were drilled fifteen to twenty years since report in the logs that comes from the Tertiary horizons. The Roberts well in Escambia County (see log, page 211) reports several showings of oil and gas. It is improbable that any of these wells were drilled on structure with the exception of the Hatchetigbee Anticline tests. The materials of the Tertiary are predominating shales and clays with thick beds of limestone and sand horizons of lesser vertical extent. The shales are generally blue to black in color. In Texas and Louisiana where these beds are penetrated there are frequent showings of oil, while a little gas is the rule rather than the exception. However, little or no production has been obtained from any of the Tertiaries with the probable exception of the salt domes along the Gulf Coast and in southwest Texas, where some oil and considerable gas is derived from the horizons above the Cretaceous.

POSSIBILITIES IN THE COASTAL PLAIN BY AREAS.

The Coastal Plain of Alabama is in this report subdivided into five areas in which the prevailing conditions are the same, based on the content of the sands, the depth to the possible horizons, the nature of the beds underlying the surface materials, the structural conditions and the possibilities of working out the structural deformations on the surface. In certain sections there are beds underlying the surface materials that have no possibility of producing oil, in others the sand horizons contain fresh water, while in other areas the subsurface conditions may be favorable but the structural conditions cannot be determined on the surface. It is a notable fact that all of the wells drilled in the southern portion of the Coastal Plain report salt water in numerous horizons while northward, up the dip of the strata, these same water-bearing sands product abundant quantities of fresh water. Analyses of the water show a gradual increase in salt content from near the outcrops to a point about 100 miles to the southward. The areas of fresh water may be eliminated as areas of possibility because of the fresh circulation of the contained liquids and the consequent dissipation of any petroleum that might have been present. These subdivisions are indicated on the map (Fig. 11, p. 42).

Area 4.—This area, consisting of Lamar and Pickens Counties and the adjoining parts of Marion, Fayette, Tuscaloosa, Greene and Sumter Counties, is covered with a comparatively thin mantle of continental sands and clays of the Tuscaloosa formation that have little or no possibility of producing petroleum. The Paleozoic strata underlying the Tuscaloosa are discussed in Part I of this report and granting that under good structural conditions the nature of the beds indicates the possibility of the presence of pools of petroleum, drilling in this area would be extremely hazardous because of the fact that the nature of the surface materials precludes the possibility of determining the structure from the surface. It is also probable that structural movements in the underlying Paleozoic were previous to the deposition of the Cretaceous and hence are not reflected in the overlying beds. Therefore, drilling in this area even though the deeper strata are petroliferous resolves itself into blind locations for tests.

Area 5.—This subdivision of the Coastal Plain embracing Hale and Perry Counties and the adjacent portions of Tuscaloosa, Bibb, Marengo, Sumter and Greene is covered along its northern half by a rather thin blanket of Tuscaloosa sands and clays under which lie the highly folded and faulted Paleozoic strata of the Valley Region. In the Tuscaloosa sands there are fresh waters only, while the underlying Paleozoics have been subjected to such metamorphism that the possibilities of commercial deposits of petroleum do not look very encouraging. The southern part of the area is overlain by the Selma Chalk while the underlying Cretaceous sands carry fresh or very slightly saline waters which is indicative of free circulation of the liquids and consequent escape of any petroleum that might have been present. No structure of consequence is known in the area.

Area 6.—Eastward from the above mentioned area there is a district of similar conditions composed of Autauga, Elmore, Montgomery, Macon, Russell, Bullock, Lowndes and Dallas Counties and the adjoining parts of Chilton and Lee on the north and Barbour and Pike on the south. The northern part of this belt is covered by sands and clays of the Lower Cretaceous series from which the nature of the materials and the fresh water content do not offer possibilities of the presence of oil. Underlying the Lower Cretaceous beds are the basement rocks of the metamorphosed Pre-Cambrian Piedmont Region, which are not petroliferous. The southern part of the belt is covered with Selma Chalk underlying which are sands and clays of the Eutaw, Tuscaloosa and Lower Cretaceous formations. All of these sands are fresh water-bearing and cannot be expected to contain deposits of petroleum in commercial quantities.

Area 7 extends as a belt across the entire State, including within its limits all of Choctaw, Clarke, Wilcox, Monroe, Butler, Crenshaw, Coffee, Geneva, Dale, Henry and Houston Counties, the southern halves of Sumter, Marengo, Pike and Barbour Counties and the northern parts of Washington, Conecuh and Covington Counties. This belt is underlain by all of the sands discussed under the heading of "Possible Sands Beneath the Coastal Plains." Also it is the area where are found all the known folds and faults of the Coastal Plain that might be favorable accumulation areas. Except along the extreme northern edge of the area all of

the sands contain salt water while numerous gas and some oil showings have been reported in the logs of several wells drilled. In the western part of this area the Ripley formation, which is one of the most promising of the Coastal Plain, is missing, or contains no sand, while below the chalk there is mostly sand for the upper 400 feet and then red beds as far as the drill has penetrated. From the Alabama River eastward the Ripley is present and increases to a maximum thickness of near 1,000 feet. In the extreme eastern part of the State the Selma-Ripley horizon is occupied entirely by the above thickness of Ripley material, there being no chalk, and seems to be the area of greatest possibility.

Area 8 comprises all of those counties south of the above described group, namely, Washington, Mobile, Baldwin, Escambia and the southern parts of Conecuh and Covington. In this district it is probable that the same conditions obtain as far as the sands are concerned as in the area to the north except that the horizons are deeper in accordance with the dip of the strata, and maybe contain fewer sands. Also there is a greater thickness of Tertiary formations to be penetrated which may or may not have possibilities of yielding oil. The nature of the surface sands precludes the possibility of determining the structural conditions; therefore, locations in the area must be made more or less blindly. This is the corresponding area to the Coastal salt dome belt in Louisiana and Texas, but as far as known none exists in Alabama. This point is discussed under "Structure."

DEPTHS TO SANDS.

The most promising formations below the Geneva Anticline, in Geneva County, are the Ripley and the Eutaw. It is not known if the Tuscaloosa is present below these formations but from the presence of the lower part of the Upper Cretaceous in west Alabama and Georgia, it is most likely present here also. Eastward from Wetumpka the Tuscaloosa is overlapped by younger formations. The nature of the Lower Cretaceous beds which unquestionably underly the southeastern corner of the State cannot be told though south of Tallahassee, Florida, it is reported that Lower Cretaceous limestones have been penetrated by the

drill, while along its outcrop it consists of continental deposits. The depth to the top of the Ripley, based on the thickness of the formations along their outcrops should be in the neighborhood of 1,200 feet. If the thickness of 1,000 feet obtains this far south, the base of the Ripley will be found at 2,200 feet, below which there should be several hundred feet of strata referable to the Eutaw formation, underlying which either Lower Cretaceous or strata of Tuscaloosa age should be encountered at from 2,500 to 2,800 feet. These depths to the formations containing the most likely sands are referable to those areas in the southeastern portion of the State in which the Claiborne formation is exposed.

On the Lower Peachtree Anticline, west of the river, the drill would begin very near the top of the Tuscahoma formation. It is estimated that the top of the Ripley will be encountered at about 750 feet with a thickness of 270 feet, which obtains in the nearest area of outcrop. The base of this formation, or the top of the chalk, would be struck at 1,020 feet after which would come a thousand feet of Selma Chalk. The drill should enter the Eutaw at 2,020 feet, estimating a thickness of 300 feet, the Tuscaloosa should be encountered at approximately 2,300 feet. The Bollinger No. 1, on the Hatchetigbee Anticline, shows about 400 feet of sands referable to the Tuscaloosa, underlying which are drill penetrated to the bottom of the well over 400 feet of Red Beds. These depths are referable to those areas over which the Tuscahoma formation comes to the surface.

DEVELOPMENT.

The first recorded drilling for petroleum in Southern Alabama was the Cullom Springs well near Mladon Springs on the Hatchetigbee Anticline in 1884-85. This test was watched by D. W. Langdon, then of the Alabama Survey, who determined Selma Chalk at 1,220 feet below the surface. The test was abandoned after the chalk had been penetrated for a short distance. After the discovery well was brought in near Beaumont, Texas, several wells were drilled in the vicinity of Mobile, and one near Roberts, in Escambia County. In 1917-18 a well was drilled to a depth of 3,400 feet by the Alahoma Oil Company in Section 26, Township 8 N., Range 1 W., on the Hatchetigbee Anticline in Clarke Coun-

ty. Later, in the spring and summer of 1918, the Empire Gas and Fuel Company drilled their Bollinger No. 1 to a depth of 4,013 feet in Section 13, Township 9 N., Range 3 W., also on the Hatchetigbee Anticline in Choctaw County. Most of these wells drilled in southern Alabama have reported gas and small showings of oil, but no production of commercial value has been obtained up to the present time. Numerous wells in the Coastal Plain of Alabama have been drilled for the purpose of securing fresh water for industrial and domestic uses. A great many of these wells, particularly north of the seaward limit of the Selma Chalk, have given the information regarding the subsurface conditions. Along the southern edge of this belt the artesian waters are generally saline and frequently have small showings of gas.

WELL LOGS.

On the following pages the logs of several wells drilled in the Coastal Plain of Alabama for oil and water with the formational subdivisions, where practicable, are given. In three wells drilled in the Hatchetigbee Anticline the Mitchell No. 1, to the east, encountered the Selma Chalk at 1,700 feet below the surface, the Cullom Springs well near Bladon Springs at 1,220 feet, and the Bollinger No. 1, near the western limit of the Hatchetigbee formation inlier, at 1,980 or possibly 1,880 feet. The log of the Bladon Springs well found the Chalk at the elevation calculated from the thickness of the formation along their outcrops to the north while the Mitchell No. 1 encountered it at the depth that would be expected without the presence of the structural uplift. The Bollinger No. 1 found the horizon still lower than the undisturbed normal dip of the formation would place it in this area.

If these logs are correct, there is a structural high in the Selma Chalk at Bladon Springs, while the chalk beneath the other two well areas does not conform to the surface structure of the Hatchetigbee Anticline. This renders the correlation of the strata above the chalk impracticable without having cuttings from the wells.

WELL RECORDS

Log of Well at Gunnet Bros. Lumber Company Mill

2½ miles southeast Myrtlewood, Marengo County, N.E. ¼ Section 29, Township 14 N., Range 2 East. Elevation 270 Feet?
Drilled March, 1920.

	Top Feet	Bottom Feet
Sucarnochee Formation:		
Soil	0	12
Soapstone (clay)	12	140
Clayton Limestone:		
Soapstone (limestone)	140	180
Selma-Ripley:		
Soapstone (chalk)	180	220
Soapstone (clay)	220	450
Soapstone (chalk)	450	700
Soapstone, very sticky (chalk?)	700	1055
Hard white rock (chalk)	1055	1099
Soft soapstone (chalk)	1099	1225
Hard blue rock (chalk)	1225	1300
Blue shale (chalk?)	1300	1375
Eutaw Formation:		
Flint rock (gas)	1375	1376
Fine-grained sand (water)	1376	1381
Blue chalk	1381	1387
Hard rock	1387	1388
Sand and broken shells	1388	1407
Rock, very hard	1407	1418
Fine white sand (water)	1418	1446
Flint (bottom of well)	1446	1449

Well supplies 5 gallons per minute of 25% saturated solution salt water. First gas struck at 1,375. Considerable gas escaping at time of writer's visit. A rainbow showed on water while well was on the pump that driller insisted came from well. May have been from tools, however.

Well of Camden Cotton Oil Company, Camden, Alabama.

	Thickness Feet	Depth Feet
Strata:		
Sand and gravel	10	10
Soapstone, laminated clay and shells	18	28
Rock	3	31
Soapstone	133	164
Ripley Formation:		
Flint rock	1	165
Lime rock	18	183
Hard rock	1	184
Sand and water	16	200
Hard rock	1	201
Clay	3	204
Sand rock	9	213
Clay	2	215
Hard rock	1	216
Lime rock?	92	308
Hard rock	8	316

Sand, shells and good stream water	34	350
Hard rock	1	351
Black dirt and good quantity mica	32	383
Flint rock	1	384
Selma chalk:		
Lime rock	146	530
Blue clay	20	550
Lime rock	245	795
White clay	38	833
Black dirt	83	916
Hard rock	2	918
Lime rock	232	1150
Blue clay	23	1173
Sand and some water	22	1195
Lime rock	40	1235

Mitchell No. 1, Alahoma Oil Company, Salitpa, Clarke County, Alabama.

S. 26, T. 8, R. 1 W.
Authority: W. C. Roark.
Contractors: J. M. Eastham, Battle House, Mobile.
Rotary Driller, W. C. Roark.
Dates: Commenced October 6, 1917; finished January 29, 1918.

	Top Feet	Bottom Feet
Tertiary:		
Clay, red, hard	.....	8
Sand, brown, soft	8	60
Shale, Gumbo, brown, soft	60	300
Rock, gray, hard	300	302
Gumbo, boulders, brown, hard	302	340
Gumbo, blue, medium hard	340	380
Rock, black, hard	380	381
Shale, gray, soft	381	400
Gumbo, blue, soft	400	470
Gumbo, blue, hard	470	520
Shell, white, hard	520	525
Shale, gray, soft	525	575
Gumbo, blue, medium	575	610
Shale, gray, soft	610	680
Gumbo, blue, hard	680	700
Gas rock (coarse S) brn. hd. Show of gas.	700	707
Shale, gray, soft	707	750
Gas rock, brown, hard Hard coarse sandstone (gas showing).	750	756
Gumbo, blue, medium	756	800
Shale, gray, soft	800	860
Shell, white, medium	860	870
Gumbo, blue, hard	870	910
Gumbo, blue, hard	910	945
Sandstone, black, hard	945	950
Shale, blue, soft	950	1010
Shell, white, hard	1010	1015
Shale, blue, soft	1015	1090
Gumbo, blue, hard	1090	1100

Rock, black, flint, hard	1100	1103
Shale, blue, soft	1103	1160
Gumbo, blue, soft	1160	1200
Rock, black, hard	1200	1202
Shale, blue, soft	1202	1300
Ripley formation:		
Rock, black, hard	1300	1304
Gumbo, blue, soft	1304	1360
Shale, blue, soft	1360	1400
Shale, gray, soft	1400	1520
Gumbo, blue, soft	1520	1600
Shale, gray, soft	1600	1640
Gumbo, blue, hard	1640	1700
Selma chalk:		
Chalk, rock, white	1700	2650
Eutaw formation:		
Little sand, soft	2650	2660
Salt water.		
Shale, white, soft	2660	2680
Gumbo, gray, soft	2680	2700
Shale, gray, soft	2700	2720
Shale, boulder, gray, soft	2720	2746
Sand, white, soft	2746	2766
Very fine salt water.		
Rock, black, medium (looks like sandy shale)	2766	2769
Gumbo, blue, medium	2769	2781
Shale, gray, soft (supposed to be top Woodbine Sand)	2781	2800
Sand, white, soft	2800	2820
Very soft, with hard spots.		
Shale, gray, soft	2820	2840
Tuscaloosa formation:		
Sand, green, medium	2840	2920
Sand, white, medium	2920	3007
Shale, gray, soft	3007	3027
Sand, light brown, medium	3027	3055
Shale, gray, soft	3055	3080
Gumbo, blue, tough	3080	3090
Sand, light brown, soft	3090	3130
Soft, with hard spots.		
Salt water.		
Shale, gray, soft	3130	3148
Rock, hard (Pyrites)	3148	3150
Shale, gray, soft	3150	3155
Rock, brown, hard	3155	3157
Sand, white, soft	3157	3191
Gumbo, blue, soft	3191	3202
Sand, white, soft	3202	3233
Shale, gray, soft	3233	3279
Gumbo, blue, hard	3279	3300
Shale, gray, soft	3300	3336
Sand, white, soft	3336	3396
Shale, gray, soft	3396	3400
Total depth		3400

Only small showings reported.

Derrick 112 feet high.

According to the log of the Mitchell No. 1, this well had almost reached the "Red Beds."

Bollinger No. 1, Empire Gas & Fuel Co., Choctaw County, Alabama.

Location: Section 13, Township 9 N., Range 3 W.
Drilling: March 28, 1918; May 16, 1918.
Casing record: 10-inch, 97 feet; 8-inch, 1142 feet; 6-inch, 2,856 feet.

	Thickness Feet	Bottom Feet
Tertiary:		
Clay, red, hard	8	8
Sand, brown, soft	15	23
Rock, blue, hard	7	30
Flint, very hard.		
Shale, blue, soft	110	140
Rock, brown, medium	5	145
Shale, blue soft	65	210
Gumbo, blue soft	80	290
Rock, black, hard	12	302
Gumbo, blue, soft	110	412
Shale, gray, soft	148	560
Sandy shale, brown, soft	90	650
Rock, black, hard	2	652
Gumbo and shale, blue, soft	98	750
Gumbo and shale, blue	90	840
Sand, green, soft	60	900
Fresh water flow.		
Shale, gray, soft	120	1020
Sand, white, hard	100	1120
Gumbo, blue, soft	22	1142
Gumbo, blue, tough	20	1162
Sandy shale, gray, soft	180	1342
Rock, brown, hard	2	1344
Gumbo and shale, gray	65	1409
Shell, white, medium	8	1417
Gumbo and shale, blue	90	1507
Shell, white, hard	12	1519
Gumbo and shale, gray	80	1599
Rock, black, hard	1	1600
Gumbo, blue, tough	30	1630
Ripley formation:		
Sandy shale, gray	120	1750
Sandy shale, gray	120	1870
Shell, white, medium	10	1880
Gumbo and shale, white	100	1980
Selma chalk:		
Chalk, rock, white, hard	40	2020
Chalk rock, white, medium	80	2100
Chalk rock, white, medium	120	2220
Chalk rock, white, hard	110	2330
Chalk rock, white, medium	110	2440
Chalk rock, white, hard	60	2500
Chalk rock, white, hard	60	2560
Chalk rock, white, soft	140	2700
Chalk rock, white, soft	80	2780
Chalk rock, white, hard	10	2790
Eutaw formation:		
Sand, white, soft	15	2805
Salt water.		
Gumbo, blue, tough	51	2856

Material	Thickness Feet	Depth Feet
Gumbo, blue, tough	15	2871
Shale, white, soft	20	2891
Shale, gray, soft	25	2916
Limestone, white, soft	10	2986
Very soft with hard brown spots.		
Lime, white, soft	160	3146
Very rotten.		
Shale, white, hard	10	3156
Shale, brown, soft	20	3176
Tuscaloosa formation:		
Sand, green, soft	59	3235
Sand packed	30	3265
Salt water show.		
Sand rock, white, hard	4	3269
Sand, white, soft	60	3329
Sad rock, white, hard	9	3338
Sand green	55	3393
Salt water flow.		
Sand, green, hard	40	3433
Sand, white, medium	50	3483
Gumbo, blue, tough	12	3495
Sand, white, hard	60	3555
Sand, white, very hard	60	3615
Lower Cretaceous(?):		
Sand, redish, hard	15	3630
Gumbo, red, tough	25	3655
Shale, red, hard	55	3710
Shale, red, medium hard	30	3740
Gumbo, red, tough	10	3750
Shale, red	55	3805
Gumbo, red, tough	20	3825
Shale and gumbo	50	3875
Very broken.		
Gumbo, red, tough	10	3885
Shale, red, hard	30	3915
Shale, red	25	3940
Shale, red	20	3960
Gumbo, red	15	3975
Shells	10	3985
Shale, red	20	4005
Sand, very hard	8	4013

T. D.

Record of Cullom Springs boring.

Hatchetigbee formation:		
Loose surface materials, varying slightly in color and texture	80	80
Alterations of blue and sandy marl (clay), with indurated blue ledge 5 feet thick at base	81	161
Soft clayey marl	23	184
Bashi formation:		
Greensand, with shells, 3 feet, followed by 22 feet alternating hard and soft beds, the latter fossiliferous and water bearing	25	209
Marls or blue clays	46	255

Material	Thickness Feet	Depth Feet
Brown and blue marls (clays) in many alterations (lignitic?)	21	276
Tuscahoma formation:		
Blue marls or clays, with 2 feet of greensand at base	61	337
Lignite, 5 feet, followed by 19 feet of brown, tough marl (clay)	24	361
Blue sandy marl, with many varieties of shells; Venericardia planicosta recognized	23	384
Blue, sandy marl (clay)	58	442
Brown marl (clay), 5 feet, with 32 feet blue marl below	37	479
Greensand marl, 9 feet, followed by 37 feet of blue marl (clay); at 500 feet water was struck which flowed 10 feet above the surface	46	525
Nanafalia formation:		
Brown clay marl, 19 feet, followed by 15 feet of blue clay with greensand, containing shells	34	559
Brown marl, resembling soapstone; contains shells; stream of water near bottom which flowed 30 feet above surface	50	609
Gray sandy marl, with shells	15	624
Gray sandy marl, with shells; more clayey than preceding	64	688
Very tough blue marl (clay), at base of which is a thin layer of white sand and then a thin layer of greensand	71	759
Naheola formation:		
Brown marl (clay), 5 feet, followed by alternating beds of clay and sand, mostly sand first salt water)	20	779
Alternations of gray and brown sand, with marl (clay)	26	805
Tough blue marl (big vein of salt water)	13	818
Sand and clay alternating	14	832
A kind of white limestone (?) containing mica, passing below into 3 feet of blue sandy marl, containing shells	28	860
Blue marl (clay), 14 feet, followed by 14 feet of blue marl and sand, numerous shells	28	888
Marl 12 feet, with streaks of sand, followed by brown sand and marl, 12 feet	24	912
Sucarnochee and Clayton formations:		
Greenish rock, chalky above, hard below	11	923
Sandstone, 4 feet, followed by 25 feet of white, blue, and gray quicksand (strong stream of salt water)	29	952
Marls or clays, mostly grayish or light brown, with several ledges of extremely hard rock, e. g., one 2 feet thick at 966 feet, one 1 foot thick at 971 feet, one 3 inches thick at 978 feet, one 1 foot thick at 1,000 feet	137	1089
Ripley formation:		
Tough black clay, 2 feet, followed by 99 feet of dark blue clay, some of it quite hard and firm, some very soft and sticky	101	1190

Material	Thickness Feet	Depth Feet
Snuff-colored clay, soft and sticky	13	1203
Gray sand and shells, 12 feet, followed by 5 feet of soft sandy clay	17	1220
Selma chalk:		
Hard ledge, 4 inches thick at top, below which are about 125 feet of moderately hard grayish or blue rock, with scarcely any change in color or texture, to bottom of boring; no shells observed; "Rotten limestone"	125	1345

The following additional notes regarding this well may be of interest: At 80 feet water was struck, but it did not overflow. At 200 feet there was a bold stream of mineral (vichy) water, which overflowed. At 400 feet another strong stream of mineral water, like the preceding. At 1,000 feet a stream of salt water with inflammable gas was struck. The present flow combines the streams at 200, 400, and 1,000 feet. The water is decidedly salt, and has a temperature of 83°. The gas collects in bubbles or in a foam on the surface of the water in the tank into which the stream flows. A lighted match touched to this foam ignites the gas, which burns over the surface of the water for some minutes, unless extinguished by accidental splash. The gas may also be ignited at the spout, where it burns with a flame 6 or 8 inches high. The estimated flow is 10 to 15 gallons per minute.

Log of Mobile Oil Company, No. 1 Well, Coden, Alabama.

	Top Feet	Bottom Feet
Upper soil	0	15
Blue clay	15	25
Lignite	25	27
Blue clay and sand	27	102
Coarse white sand	102	117
Gravel	117	152
Stiff blue clay	152	174
Blue sand	174	180
Blue shale and shells	180	202
Blue clay	202	254
Sand	254	259
Blue clay	259	274
Coarse white sand	274	320
Blue shale and shells	320	340
Blue shale	340	375
Sandstone	375	378
Gravel	378	379
Gumbo	379	394
Blue sand	394	404
Blue shale	404	409
Blue sandy clay	409	454
Blue clay	454	477
Sand	477	492
Blue shale	492	521
Sand	521	531
Blue shale	531	571
Gravel	571	576
Blue shale	576	626

	Top Feet	Bottom Feet
Blue shale and shells	626	628
Blue clay	628	648
Sand	648	670
Blue shale and lignite	670	672
Blue shale and rotten shells	672	692
Sand and shells	692	712
Shale	712	731
Gumbo	731	751
Shale and shells	751	771
Shale and small shells	771	780
Blue clay	780	810
White sand	810	815
Gumbo	815	840
Sand, salt water and gas	840	899
Gravel	899	946
Gray clay	946	967
Blue clay	967	984
Shale and shells	984	1007
Sand	1007	1030
Blue clay	1030	1059
Blue shale	1059	1070
Blue clay	1070	1092
Conglomerate pebbles	1092	1094
Hard blue shale	1094	1110
Sand rock	1110	1112
Gumbo	1112	1148
Sand rock	1148	1153
Gumbo	1153	1156
Sand rock	1156	1164
Gumbo	1164	1169
Sand rock and gas	1169	1173
Blue clay and lignite	1173	1196
Hard rock	1196	1200
Gumbo	1200	1212
Rock	1212	1214
Gumbo and lignite	1214	1224
Rock	1224	1231
Fine sand	1231	1236
Rock	1236	1238
Blue clay and shell	1238	1246
Gumbo	1246	1258
Shale	1258	1283
Rock	1283	1285
Gumbo	1285	1308
Shale	1308	1353
Gumbo	1353	1438
Limestone, blue	1438	1440
Limestone and shale	1440	1452
Lime rock	1452	1459
Sand and shells—gas and salt water	1459	1519
Limestone	1519	1526

T. D.

ROBERTS.

The deepest boring made in Escambia County is a well bored for oil on the banks of Conecuh River, 6 miles above Roberts. Unfortunately samples of the materials penetrated at different depths could not be obtained except in a few instances. At a depth of 100 feet the St. Stephens limestone was struck, and the boring was still in the same rock at the depth of 190 feet. Claiborne shells were brought up in abundance before the drill had gone 700 feet. As nearly as can be determined the boring must have gone to the base of the Tertiary, if not into the Ripley beds.

A great volume of water was struck at less than 700 feet. It was estimated that, when half shut off, this flow was 3,000 gallons per minute, and much greater before being reduced.

The boring was done by M. Canfield in 1902-3. The Grand Gulf sands are at the surface, and the lower part of the river bluff is formed by the calcareous sands of Miocene age, while the top of the St. Stephens limestone is not far below the water level in the river, since it shows in the banks a few miles upstream. The water which pours out of this well is beautifully clear and blue, such as is seen in limestone springs, and is decidedly limy.

The record as given by Mr. Canfield is as follows:

Record of Well at Roberts.

	Feet	Feet
Sand	0	22
Blue marl	22	37
Fine white sand	37	39
Gumbo	39	60
Lime rock and shell	60	61½
Gumbo	61½	90
Layers of shell rock and blue clay, 1 or 2 inches thick	90	90
Blue clay, 1 foot; white shell rock, 2½ feet; blue clay, shell rock, 5 feet; very hard flint rock, 6 inches; soft lime rock, 2 feet; blue clay, 2 feet	100	113
Lime rock	113	120
Hard lime rock, 18 inches; soft lime rock, 2½ feet; hard lime rock, 2 feet	120	126
Lime rock; small slow at about 150 feet	126	234
Lime and sand shale (water)	234	248
Sand rock	248	317
Lime and sand (water)	317	337
Hard sand rock (water)	337	347

	Feet	Feet
Black muck, green clay, lignite, trace of oil; strong flow of water (3,000 gallons per minute)*	347	353
Lime rock, lignite, oily sand	353	363
Shale	363	365
Sandy shell rock	365	375
Shell rock	375	388
Sandy shale	388	401
Soft, honeycombed lime rock	401	413
Gumbo (sea sediment)	413	416
Hard shell rock	416	427
Soft sand rock, lignite	427	441
Lignite	441	446
Sand	446	466
Soft lime rock, becoming harder	466	480
Honeycombed lime rock (water)	480	490
Hard lime rock	490	505
Blue marl	505	506
Lime rock	506	522
Soft lime	522	524
Sand, strong flow of water, nearly as great as that at 350 feet	524	526
Lime rock, sandy at times	526	588
Sandy shale	588	600
Lime rock, part shells	600	629
Blue sand shale	629	639
Lime rock	639	653
Sand and shale; at 675 feet good flow of water	653	698
Lime rock; thin stratum of coal in last 30 feet	698	748
Shell rock (cap rock)	748	758
Sand rock, much mica	758	764
Shell rock	764	773
Hard slate	773	813
Shell and lime rock	813	821
Sand	821	831
Shell and sand	831	911
Pyrite	911	912
Blue marl	912	923
Gumbo, some shell	923	958
Chalk	958	960
Gumbo	960	968
Soft sand rock	968	988
Sand rock	988	992
Pyrite	992	999
Gumbo, streaks of shale	999	1148
Dark clay	1148	1154
Hard lime rock, shells	1154	1158
Clay, like lime	1158	1159
Lime, shells, sand rock	1159	1164
Gumbo, some gas	1164	1214
Porous lime rock	1214	1220
Shale	1220	1240
Soft, porous black rock, oil sand	1240	1245
Dark shale	1245	1290
Dark green sand	1290	1305

*The water from 350 feet came up through a 12-inch pipe 22 feet above the ground, then 8 feet through a 4-inch pipe, in all 30 feet. From the top of this pipe a 4-inch stream was projected 35 feet into the air, 65 feet above the ground surface.

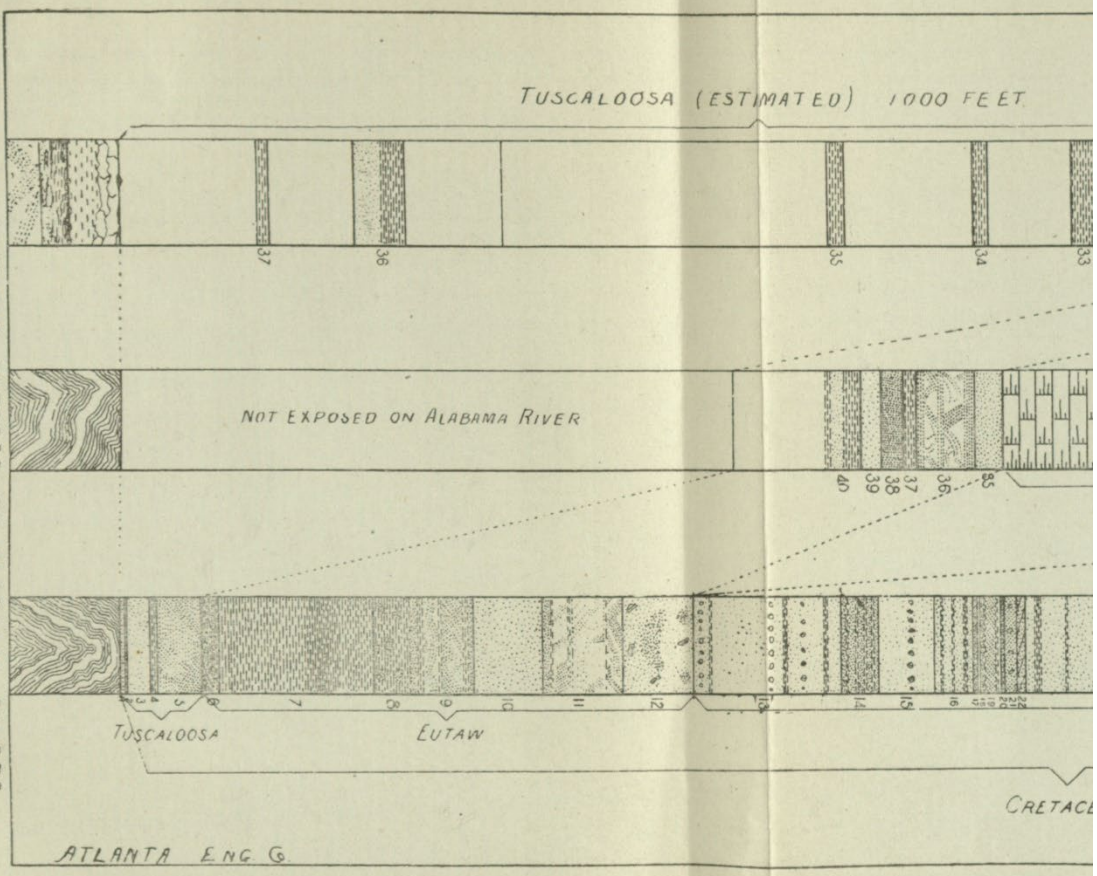
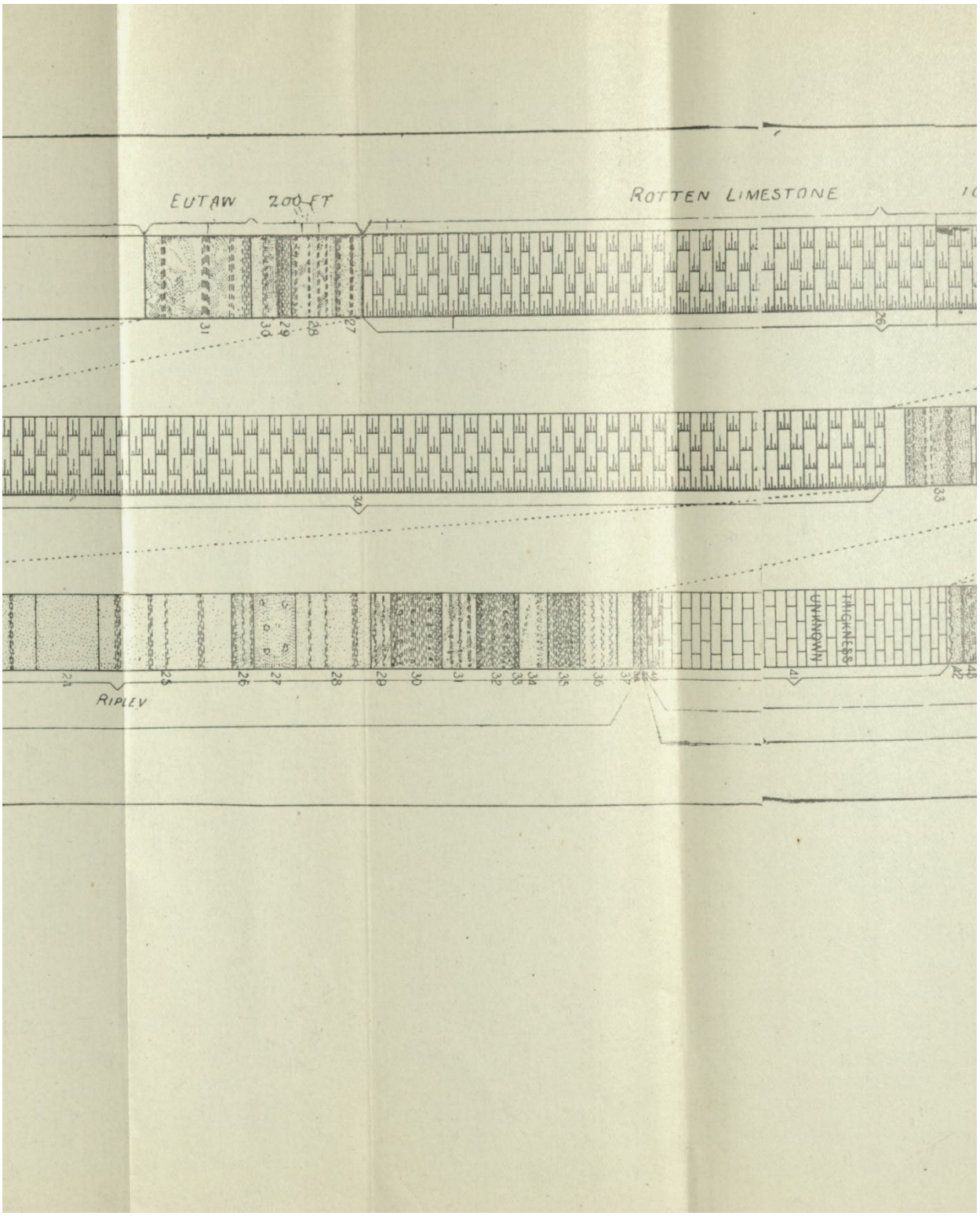
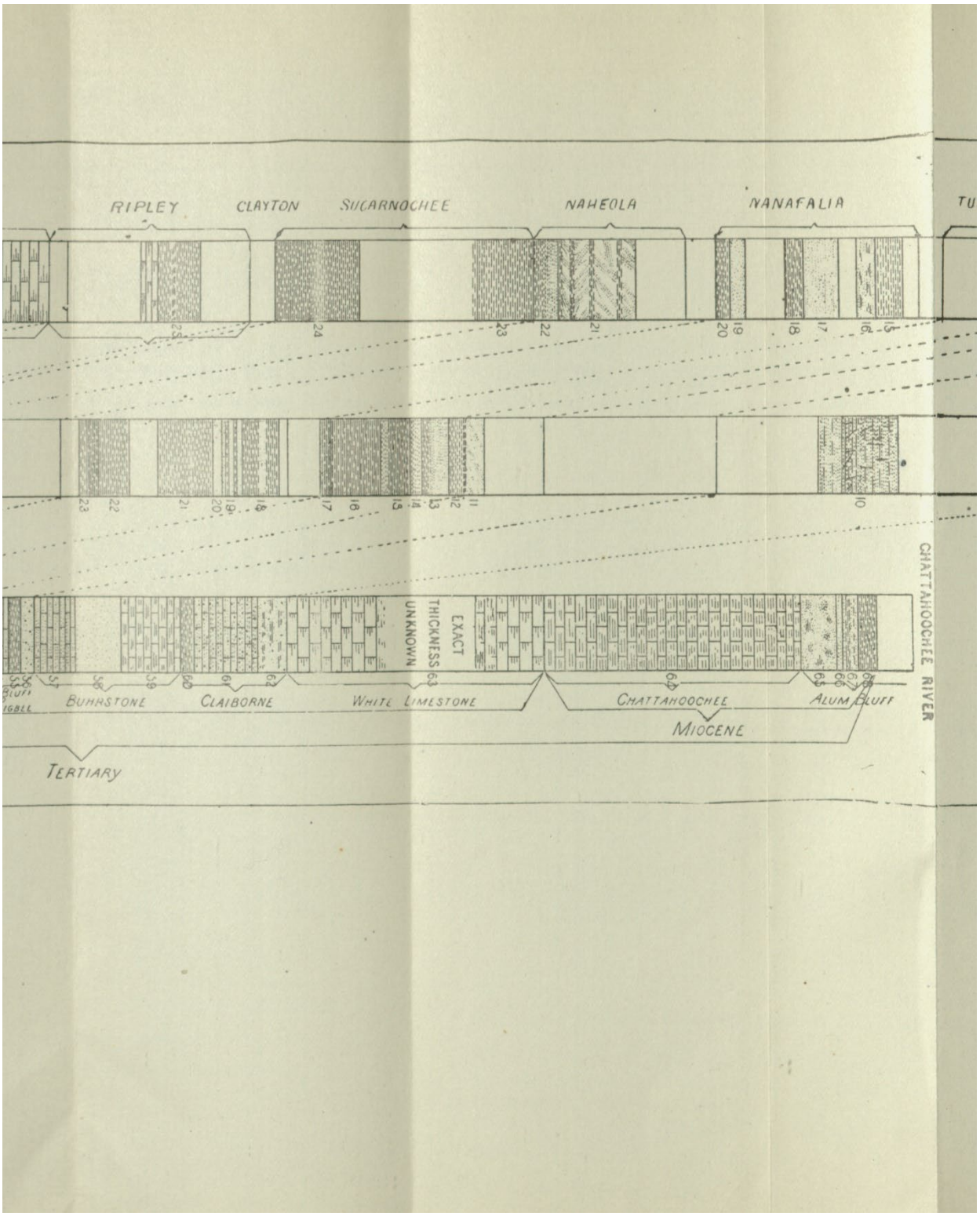
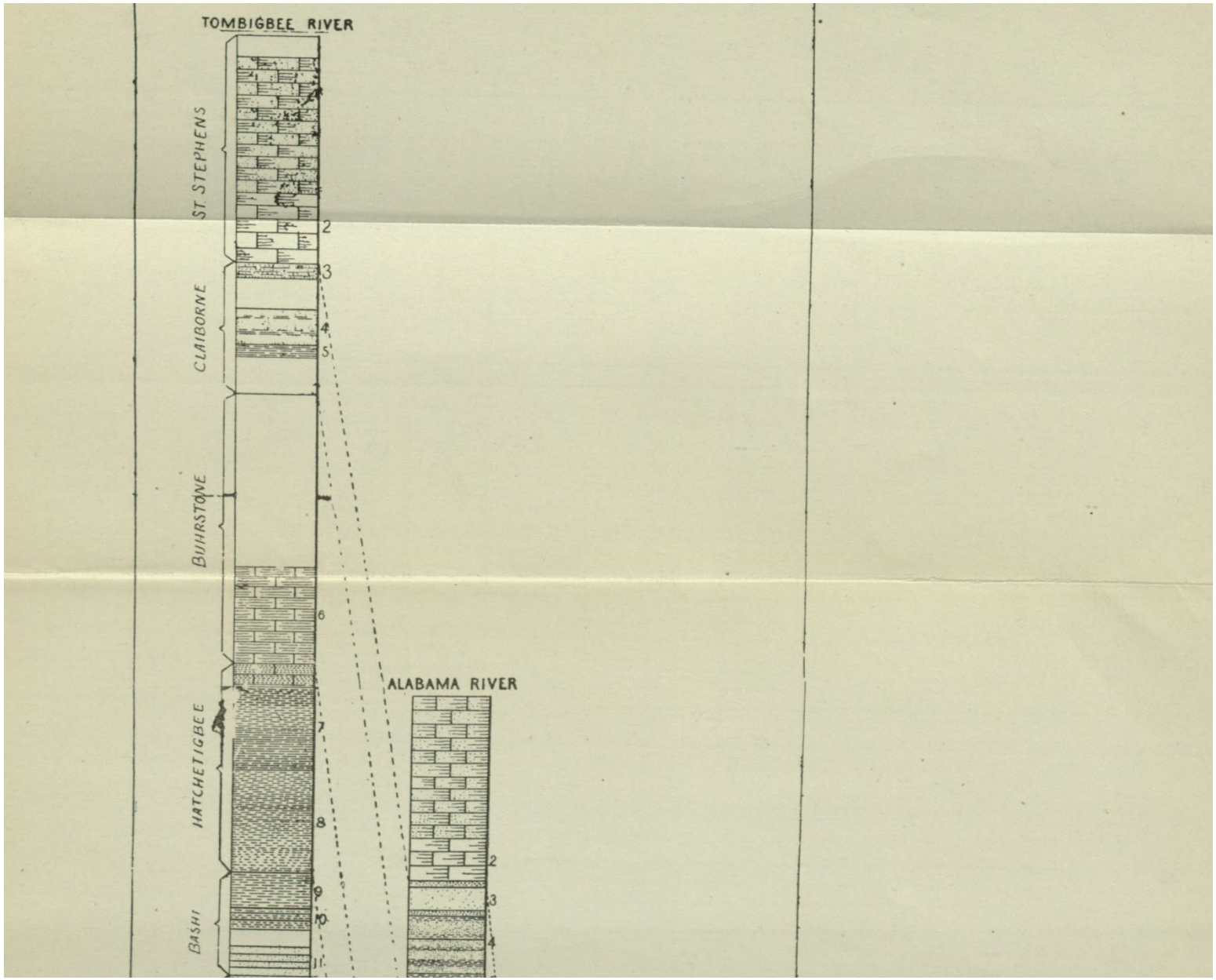

GENERAL SECTIONS EXPOSED ON ALABAMA RIVERS.
SCALE ONE INCH = 150 FEET
TUSCALOOSA (ESTIMATED) 1000 FEET
NOT EXPOSED ON ALABAMA RIVER
TUSCALOOSA
EUTAW
ATLANTA ENG CO

Fig. 27.


EUTAW 200 FT
ROTTEN LIMESTONE
UNKNOWN THICKNESS
RIPLEY


RIPLEY
CLAYTON
SUCARNOCHEE
NAHEOLA
NANAFALIA
TU
CHATTAHOOCHEE RIVER
EXACT THICKNESS UNKNOWN
BUHRSTONE
CLAIBORNE
WHITE LIMESTONE
CHATTAHOOCHEE
ALUM BLUFF
MIOCENE
TERTIARY


TOMBIGBEE RIVER
ST. STEPHENS
CLAIBORNE
BUHRSTONE
HATCHETIGBEE
BASHI
2
3
4
5
6
7
8
9
10
11
ALABAMA RIVER
2
3
4

	Feet	Feet
Soft rock	1305	1310
Dark shale	1310	1320
Gumbo with shell	1320	1337
Soft sand rock	1337	1350
Dark shale	1350	1355
Shells, lime rock	1355	1360
Dark shale	1360	1375
Soft sand rock	1375	1380
Dark shale	1380	1390
White clay	1390	1400
Soft sand rock, black specks	1400	1410
Sandy shale, black specks	1410	1422
Dark shale	1422	1439
Pyrites, shells, sand and rock mixed together, salt water, flow 150 gallons per minute	1439	1484
Dark shale, hard streaks and some shells	1484	1522
Dark clay or gumbo	1522	1550
Hard flinty rock	1550	1553
Gumbo shale, some shells	1553	1640

At this depth the formation should be lower Nanafalia or Naheola.
At 1300 feet a petrified sea-crab shell was found.
At 1600 feet, salt water about 200 gallons per minute.

General Section exposed along the Alabama Rivers.

From Coastal Plain Report.
Figure 27, Column 1, *Tombigbee River.*

1. Vicksburg. White Limestone with *Orbitoides mantelli*, forms upper 70 feet of Saint Stephens Bluff, upper part of Baker's Hill, and greater part of river bluffs down to Oven Bluff ..... 140 feet
2. Jackson. Argillaceous White Limestone lower part of Saint Stephens and Baker's Bluffs ..... 60 feet
3. Scutella beds, underlaid by coarse greensand and Claiborne fossiliferous sands ..... 15 feet
4. Yellowish gray, calcareous sands, with *Ostrea sellaeformis*, clayey in part, traversed by hard, sandy ledges, greensand, with comminuted shells at base ..... 35 feet
5. Bluish clay ..... 7 feet
6. Aluminous sandstones, claystones, etc., of jointed structure, forming at White's Bluff a perpendicular cliff ..... 115 feet
7. Brown clays, sandy, non-fossiliferous, 30 feet, followed by 3 feet marl and 15 feet purplish brown, sandy clays; then 28 feet of sands striped with brown clays and inclosing two beds with marine shells; in all ..... 75-76 feet
8. Dark gray, sandy clays, striped with brown or purple, sandy clays. Very few fossils exposed at Davis's Bluff, White's Bluff and McCarthy's Bluff ..... 100 feet
9. Clayey marl, passing into a greensand marl 18 feet thick (Wood's Bluff marl) ..... 31 feet
10. Gray, clayey sands, with four or more thin seams of lignite ..... 25 feet
11. Laminated sands and indurated sands, with boulders ..... 30 feet
12. Gray, sandy clays, striped with somewhat harder, projecting ledges ..... 35-40 feet

13. Greensand marl (Bell's Landing) ..... 7 feet
14. Sandy, laminated clays ..... 15 feet
15. Gray, sandy clays, rather thin bedded; hard, sandy ledge at base ..... 28 feet
16. Glauconitic sands and clays, with *Gryphaea thirsae* ..... 18 feet
17. Glauconitic sands, with *Gryphaea thirsae*, at Lott's Ferry, Eureka Landing, and Nanafalia Landing ..... 35 feet
18. Black clay, passing into a greensand marl, with *Gryphaea thirsae* ..... 18 feet
19. Black, micaceous, glauconitic sands ..... 15 feet
20. Lignite 7 feet and 5 feet gray clay below ..... 12 feet
21. Gray, sandy clays, cross-bedded sands and laminated clays in many alterations ..... 80 feet
22. Greensand marl (Naheola), with black clay below ..... 20 feet
23. Between Naheola and Black Bluff, black clays, thickness unknown.
24. Yellowish clays 30 feet, underlaid by 50 feet of black and dark brown, slaty, fossiliferous clays, Black Bluff fossils ..... 80 feet
25. Dark blue or black, sandy clays, with indurated bands, calcareous below, passing into an argillaceous limestone 16 to 18 feet, with phosphatized shell casts (Ripley) ..... 55 feet
26. Argillaceous limestone, with hard ledges, holding many shells (*Ostrea*, *Exogyra*, *Gryphaea*) (Rotten Limestone) ..... 1,000 feet
27. Hard, calcareous sands, highly fossiliferous, 6 to 8 feet; thin, yellow, cross-bedded sands, 15 feet; and below this a phosphatic greensand, 8 to 10 feet ..... About 25 feet
28. Cross-bedded, glauconitic sands with thin clay partings, yellowish color prevailing ..... 40 feet
29. Dark gray, laminated, sandy clays, alternating with bluish sands ..... 15-20 feet
30. Laminated sands and clays, alternating with cross-bedded sands ..... 40(?) feet
31. Compact, micaceous sands, cross-bedded sands, laminated clays in many alternations, including two small beds of pebbles and thin bed of lignitic matter ..... 60(?) feet
32. Purple and mottled clays, 10 feet, with 15 feet of yellow, micaceous sands below ..... 25 feet
33. Purple and mottled clays, 10 feet, with 10 feet light yellow, coarse, cross-bedded pebbly (chert) sands ..... 20 feet
34. Purple and mottled clays ..... 10 feet
35. Purple and mottled clays ..... 10 feet
36. Dark gray, laminated clays, sandy partings, 25 feet, and gray sand indurated, 15 feet, at Venable's and near Saunders' Ferry ..... 40 feet
37. Sandy clays, with leaf impressions, black scales like graphite fragments of lignitized stems.

Figure 27, Column 2, *Alabama River.*

1. Vicksburg. White Limestone, with *Orbitoides mantelli;* hill back of Claiborne, also back from river, from Marshall's Landing to Gainestown ..... At least 140 feet
2. Jackson. Argillaceous White Limestone, with bones of *Zeuglodon cetoides*, phosphatic nodules, and marls, from Claiborne to Marshall's Landing ..... 60 feet

3. Scutella bed, followed by coarse, ferruginous sands, of which 17 feet is highly fossiliferous; hard, sandy ledge at base ..... 30 feet
4. Calcareous clay, alternating with greensand containing *Ostrea sellaeformis* ..... 25 feet
5. Light gray calcareous sands, traversed by hard, sandy ledges, clayey in part, *Ostrea sellaeformis* characteristic greensand, and shells at base ..... 35 feet
6. Blue clay, passing into greensand, upper half with fossils, lower half highly fossiliferous ..... 22 feet
7. Calcareous, clayey sands ..... 9 feet
8. Coarse ferruginous marl 3 feet followed by 20 feet of light yellow sands, few fossils ..... 23 feet
9. Bluish, jointed clay ..... 12 feet
10. Light colored, aluminous sandstones, claystones, and siliceous sandstones ..... 75 feet
11. Reddish, cross-bedded sands, 2 feet lignite at base ..... 22 feet
12. Laminated, sandy clays, gray color ..... 15 feet
13. Yellow sands, passing below into gray, laminated, sandy clay ..... 25 feet
14. Greensand marl, Bell's Landing ..... 10 feet
15. Gray, laminated, sandy clays 22 to 23 feet, passing into clay marl, Gregg's Landing, 5 feet ..... 30 feet
16. Sandy clays of prevailing gray color, varying in degree of sandstone and coarseness of lamination, 1 foot greensand marl at base ..... 50 feet
17. Gray, sandy clays ..... 10 feet
18. Gray, sandy clays, alternately thin, laminated, and heavy bedded; indurated by glauconitic clay on top and greensand bed in middle ..... 37 feet
19. Glauconitic sands, with *Gryphaea thirsae*, indurated ledges passing through beds ..... 18 feet
20. White cross-bedded sands ..... 12 feet
21. Bluish, clayey, glauconitic sands, with *Gryphaea thirsae* several hard ledges ..... 50 feet
22. Glauconitic, clayey sands of varying degree of hardness, bed of lignite 4 feet (Coal Bluff) at base ..... 35 feet
23. Gray, sandy clays ..... 10 feet
24. Gray clay, cross-bedded sands, Burford's Landing ..... 10 feet
25. Gray, sandy clays, forming river banks from Walnut Bluff to Clifton ..... 35 (?) feet
26. Black, sandy clay marl, micaceous, Matthews's Landing ..... 20 feet
27. Black clay, Midway ..... 5 feet
28. Argillaceous White Limestone (*Nautilus Rock*) ..... 10 feet
29. Crystalline limestone (*Turritella*) back of Bridgeport .....
30. Yellowish, micaceous sand (Ripley fossils) at Bridgeport and hills back of landing ..... 55 feet
31. Dark bluish gray, sandy, micaceous clays, weathering into yellowish shales, with indurated, sandy, projecting ledges at intervals of 5 to 10 feet throughout whole thickness, exposed at Bridgeport, Tear Up Creek, Canton Landing, and hills back of Prairie Bluff and in Gee's Bend ..... 100 feet
32. Bluish, argillaceous limestone, with phosphatized shell casts, etc., Ripley formation ..... 30-35 feet
33. Sands of various colors, dark blue, gray to white, traversed by indurated bands of calcareous sands with Cretaceous shells ..... 60 feet
34. Highly argillaceous limestone, with ledges holding many shells, *Ostrea*, *Gryphaea*, *Exogyra* ..... 1,000 feet

35. Hard, calcareous sands, with fossils strongly phosphatic in part ..... 20 feet
36. Alternating layers of horizontally laminated and cross-bedded, yellowish (glauconitic) sands ..... 40 feet
37. Laminated blue clays ..... 10 feet
38. Blue, micaceous sands ..... 15 feet
39. Light colored micaceous sand ..... 20 feet
40. Laminated clays and blue sands, thickness not determined.

Figure 27, Column 3, *Chattahoochee River.*

Lower Cretaceous:

1. Light green, highly micaceous sand, resembling weathered schist; but for occasional water-worn quartz pebbles might be taken for schist ..... 3 feet
2. Hard clay stained by ferruginous matter; breaks with conchoidal fracture ..... 1 foot
3. Hard, white, coarse-grained sand, held together by white clay ..... 15 feet
4. Red and gray variegated sandy clay (typical Tuscaloosa); Shown at water's edge, mouth of Bull Creek, Georgia ..... 6 feet
5. Strongly cross-bedded coarse sand and pebbles with some few fragments of schist and just enough white clays to hold the mass together. The quartzose pebbles are all well water-worn, while the softer bits of schist are but a slightly abraded. The stratum varies in color from white to lemon yellow and in places green, while the upper becomes mottled purple and yellow. This last phase is most strongly developed at Thomas's bluff, Georgia, due east of Fort Mitchell, Alabama. Top of the Tuscaloosa ..... 40 feet

Upper Cretaceous—Eutaw Formation:

6. Dark gray calcareous sand, pyritous and containing nodular masses 6 to 12 inches in diameter with calcite nuclei. These nodules are arranged in strata about 2 feet apart and terminate in an indurated stratum about 12 inches thick. Small fragments of lignite are scattered about through this stratum, and one or two large masses filled with calcified teredos were found. The only other fossils seen were an *Anomia* and an *Exogyra*, probably the young of E. *costata* (?), Say. The fossils are all poorly preserved. Dip at this point, 40 feet to the mile southward ..... 15 feet
7. Gray sands of the same nature as the preceding, only to nodules were seen, and the shells increase in quantity, particularly in the lower part. The upper part of the stratum becomes argillaceous and contains many fossil casts, mainly lamellibranchs, causes landslides in the banks like the Black Bluff clays, which they resemble somewhat physically. These sandy clays give rise to Uchee shoals ..... 100 feet
8. Laminated dark gray clays, with masses of yellow sand distributed at irregular intervals throughout the stratum; best developed just above Uchee Creek, Alabama ..... 25 feet
9. Yellow and white sands, with thin seams of lignitic sand and an occasional "bunch" of gray laminated clay. These sands are exposed in a bluff about 100 yards from the river, just south of Rooney's Mill Creek, Georgia ..... 50 feet

10. Quartzose conglomerate much like that at Havana, Hale County, Alabama; forms the shoal at Beden's rock and the bluff at Hatcher's lower landing; merges gradually into a yellow sand ..... 50 feet
11. Yellow sand and gray clay, containing bits of leaves. This stratum and the following are seen at Chimney Bluff, Alabama ..... 60 feet
12. Light yellow and white sands, containing beds of well-rounded quartzose pebbles, sometimes 20 feet thick. Lignitized logs can be seen protruding from the bluffs. The sands contain a small Exogyra at rare intervals. The supposed top of the Eutaw group ..... 45 feet
13. Gray, sandy calcareous clay, with lines of bowlder-like concretions projecting from the bank; first seen at Lawson's wood yard, Georgia. Few fossils occur in the lower part of this stratum. *Exogyra costata*, Say, a mile above Blufftown, Georgia, where characteristic Ripley shells, mainly bivalves, are found in a much decomposed state throughout a stratum 6 to 8 feet thick. The uppermost 10 feet of the stratum is very fossiliferous. The river washes out little cave-like recesses in the banks. Near Jernigan's Landing, Alabama, slight rolls in the strata are seen involving about 20 feet of the sands, and these miniature anticlinals and synclinals continue to within two miles of Florence, Georgia. The dip, estimated from the line of bowlders, averages about 20 feet to the mile and is normal in direction ..... 120 feet
14. Two miles above Florence, Georgia, and making part of a bluff 50 feet high at that place, there is a gray sand interlaminated with thin seams of a more argillaceous sand, all of which is unfossiliferous. Dip here about 40 feet to the mile ..... 26 feet
15. Gray calcareous sands, containing a small fragile Anomia and a line of hard, round concretionary bowlders ..... 40 feet
16. Gray and yellow sands, resembling in physical character those of the Tertiary at Lower Peach Tree, Alabama ..... 30 feet

Ripley Formation:

17. Gray, highly fossiliferous marl. The fossils are nearly, if not quite, all bivalves, and are mostly comminuted as if they formed an ancient shore-line. There are numerous shark teeth and a hard black substance resembling in sections the under shell of a turtle, black coprolitic (?) pebbles, and fragments of lignite ..... 3 feet
18. Sandy stratum, indurated and containing Ostrea, sp. ..... 1 foot
19. Cross-bedded gray sands and clay ..... 15 feet
20. Fossiliferous marl, about the same in general character as 17, only little or no lignite was seen, the marl appearing to be somewhat glauconitic. (The strata from 17 to 21, inclusive, form a bluff on the eastern bank five miles below Florence, Georgia ..... 2 feet
21. Gray, glauconitic, and calcareous sand, weathering into fucoidal masses and containing a few soft white phosphatic nodules ..... 10 feet
22. Gray, fossiliferous marl, shells much decomposed. An occasional lignitized log and numerous slightly phosphatic nodular masses containing fossils occur in this stratum 5 feet
23. About the same in general character as 21, but contains indurated ledges about a foot thick, which show the dip

to average 40 feet to the mile, with numerous rolls; ends just above the mouth of Cowikee Creek, Alabama ..... 170 feet

24. Soft, less coherent sand, gray in color; appears at the mouth of Cowikee Creek, Alabama, from which the southern bank of the creek, composed of this stratum, may be seen to rise 50 feet from the water ..... 60 feet

25. Gray calcareous sand, with indurated ledges, containing *Exogyra costata*, Say; *Gryphaea vesicularis*, Lam; *Hamulus onyx*, *Plicatula urticosa*, *Anomia*, sp.; forms the shoals at Frances bar and bluff at Eufaula, Alabama ..... 190 feet

26. Light gray and yellow sands, interlaminated with sand darker in color, more argillaceous, and containing bits of lignitized leaves and twigs; no other fossils seen; crops out in the gullies of Eufaula next below the Orange sand ..... 20 feet

27. Massive gray sand, with a few fragile fossils and bowlders. This sand is only slightly calcareous, and is more or less lignitic; dip here about 100 feet to the mile ..... 40 feet

28. A more calcareous sand, filled with *Exogyra costata*, Say, and many indurated ledges, giving rise to the first bar below Eufaula ..... 70 feet

29. Light yellow cross-bedded sands enclosed between indurated ledges ..... 20 feet

30. Calcareous gray sands, with bowlders ..... 50 feet

31. Yellow sands and indurated ledges filled with casts, *Exogyra costata*, Say, and echinoids set fast in the ledges. The sands are cross-bedded and contain some lignitic streaks ..... 35 feet

32. Gray fossiliferous sand, with bowlders. The sand is massive, and is fossil-bearing only in the lowest 5 feet ..... 40 feet

33. Brown laminated argillaceous sand; disappears at the mouth of Pataula Creek, Georgia ..... 5 feet

34. Light yellow sand, interstratified very irregularly with a gray micaceous sand filled with friable Ripley fossils; mouth of Pataula Creek, Georgia ..... 30 feet

35. Hard sandy ledge; weathered surface jagged; contains *Exogyra costata*, Say, and echinoids; very light yellow in color, white when dry and not weathered ..... 30 feet

36. Gray sand, with indurated ledges; no fossils seen, merges gradually in the upper part into a dark, almost black, sand containing large nodular masses and interstratified with light yellow sands ..... 35 feet

37. White coarse conglomerate, the matrix material being calcareous. The quartzose pebbles decrease in size toward the top, and the stratum becomes more argillaceous. There are many casts, but all too obscure for identification ..... 18 feet

38. Massive blue clay; contains a few bits of teredo-eaten lignite (probably top of Cretaceous) ..... 6 feet

Tertiary—Midway (Clayton formation):

39. Massive sandstone; coarse-grained and almost a conglomerate ..... 8 feet

40. Light-yellow siliceous sandstone, containing a large *Ostrea* and numerous obscure casts; five miles above Fort Gaines, Georgia ..... 10 feet

41. White calcareous sand, containing a few obscure casts and an *Ostrea*. The sand sometimes becomes irregularly indurated, and is the source of numbers of small lime springs; forms the lowest part of the bluff at Fort

Gaines, Georgia, and in its uppermost 10 feet contains pockets of white sand, enclosed by black clay, the clay resting in "potholes" in the limestone; estimated at ..... 200 feet

Wilcox Group—Nanafalia Formation:

42. Glauconitic sand filled with *Gryphaea thirsae*, Gabb; *Venericardia planicosta*, and *Crassatella tumidula* ..... 8-12 feet
43. Gray, calcareous sandy clay, containing bowlders of clay and a few decomposed shells of *Gryphaea thirsae* ..... 15 feet
44. White and lignitic cross-bedded sands, and sandy gray clay containing one or two ledges of "pseudo-buhrstones" ..... 50 feet
45. Dark gray argillaceous sand, with few fossils and fragments of water-worn clay balls. The lower part becomes more fossiliferous, containing *Osteodes caulifera*, *Venericardia planicosta* and *Gryphaea thirsae*, etc. ..... 6 feet
46. Greenish-gray, fine-grained calcareous sand; very firm, and holding decomposed shells, mainly bivalves ..... 6 feet
47. Coarse glauconitic sands filled with very large shells of *Ostrea compressirostra*, *Venericardia planicosta*, and a small *pecten* resembling the species occurring at Yellow Bluff, on the Alabama ..... 3 feet
48. Cross-bedded yellow sands, the bedding planes being marked by streaks of gray clay ..... 10 feet
49. Yellow and gray sandy clays, containing occasional beds of *Ostrea compressirostra* and *Gryphaea thirsae*. The indurated ledges (seldom over two feet thick) which sometimes occur are of the nature of "pseudo-buhrstone," and are filled with bivalves, the only exception noted being *Turritella mortoni* (large). This member disappears below the surface at the mouth of the first large creek flowing from the Georgia side below Fort Gaines ..... 75 feet

Tuscahoma Formation:

50. Light yellow and gray sandy clays, containing in the sandier portion bowlders much like those seen at Bell's Landing; no fossils seen. These are undoubtedly the Lower Peach Tree clays and sands. They become more sandy on ascending ..... 170 feet

Bashi Formation:

51. Light greenish yellow sand filled with bits of decomposed shells and large specimens of *Ostrea compressirostra* and *Venericardia planicosta*. (Interval of 50 yards) ..... 3 feet
52. Gray sand filled with decomposed fossils. An irregular indurated ledge (non-fossiliferous) occurs in this stratum. This is probably Bashi, though the only fossil that could be determined with any degree of accuracy is the small oyster so common at the typical locality ..... 18 feet
53. Blue, slightly sandy clay ..... 6 feet
54. Light yellow, siliceous (sandy) limestone filled with casts and containing pockets filled with shells of *Ostrea compressirostra* ..... 18 feet

Hatchetigbee Formation:

55. Gray lignitic sandy clay (Hatchetigbee) ..... 10 feet

Claiborne:

56. Coarse white sand, containing *Ostrea divaricata* and a few other friable shells in the upper part. (The first flexures since leaving Eufaula occur in this stratum ..... 12 feet

57. Plain buhrstone, rather sandy ..... 40 feet
58. Light, yellowish green sand containing numbers of small shells of *Ostrea sellaeformis* ..... 45 feet
59. Buhrstone ..... 55 feet
60. Greenish-yellow calcareous clay, with a few decomposed fossils and an occasional large shell of *Ostrea sellaeformis* ..... 12 feet
61. White sandy limestone, with small shells of *Ostrea sellaeformis* in abundance and pockets of larger sized shells. Makes capping ledge to island at mouth of Omussee Creek, where the bluff is about 20 feet high. This stratum is made up of alternate beds of hard and soft strata, all containing more or less abundant remains of *Ostrea sellaeformis*. The harder strata weather out into root-like shapes, and are sometimes rather argillaceous. Many return dips occur in this stratum, stringing it along the banks for many miles further than it would extend normally. The dips are all steep both ways, and many gaps in the succession are caused by the washing out of their softer strata. Owing to these gaps and return dips, it is rather difficult to estimate the thickness of this stratum with much accuracy. It dips below the surface of the river two miles below Gordon, Alabama, and is last seen on the Georgia bank. At Gordon there is a very pronounced return dip. Estimated at (and not exceeding) ..... 60 feet

Jackson Formation:

62. The "Scutella bed;" weathers so as to make it impossible to "count up" its thickness. It is literally full of fossils, mainly *Scutella lyelli*(?) and *Pecten nuperus*, with a few smaller and thicker shells of *Scutella*. A bluff about 20 feet high occurs opposite the mouth of Cowhatchee Creek, Georgia ..... 25-30 feet

Oligocene—Vicksburg Formation:

63. White orbitoidal limestone, seen first at Dougherty's woodyard (Georgia), on the Alabama bank, 9 miles by river from Neal's Landing, Alabama. The limestone contains numbers of echinoids about five miles above Neal's. The limestone continues as far as Miriam's landing, at which place the thickness is ..... 200 feet

Chattahoochee and Alum Bluff:

64. Argillaceous and sandy limestone, alternating with strata of purer character. Contains a *Pecten* and an *Ostrea* very close to our recent *virginica*. This may be termed the Chattahoochee limestone. It is well developed there and in the eastern river bank for the succeeding 10 miles ..... 25 feet
65. Light yellow sand, containing pockets of fossils. Where there are no shells the sand is very calcareous. Fossils resemble those described by Conrad as Miocene from York County, Virginia, and Maryland ..... 35 feet
66. Gray sand, slightly calcareous ..... 5 feet
67. Gray calcareous sand filled with shells. The leading fossil is a Mactra ..... 10-15 feet
68. Black lignitic sand. This contains pyrite, and from the efflorescence of ferrous sulphate arises the name Alum Bluff; varies with preceding ..... 15-15 feet

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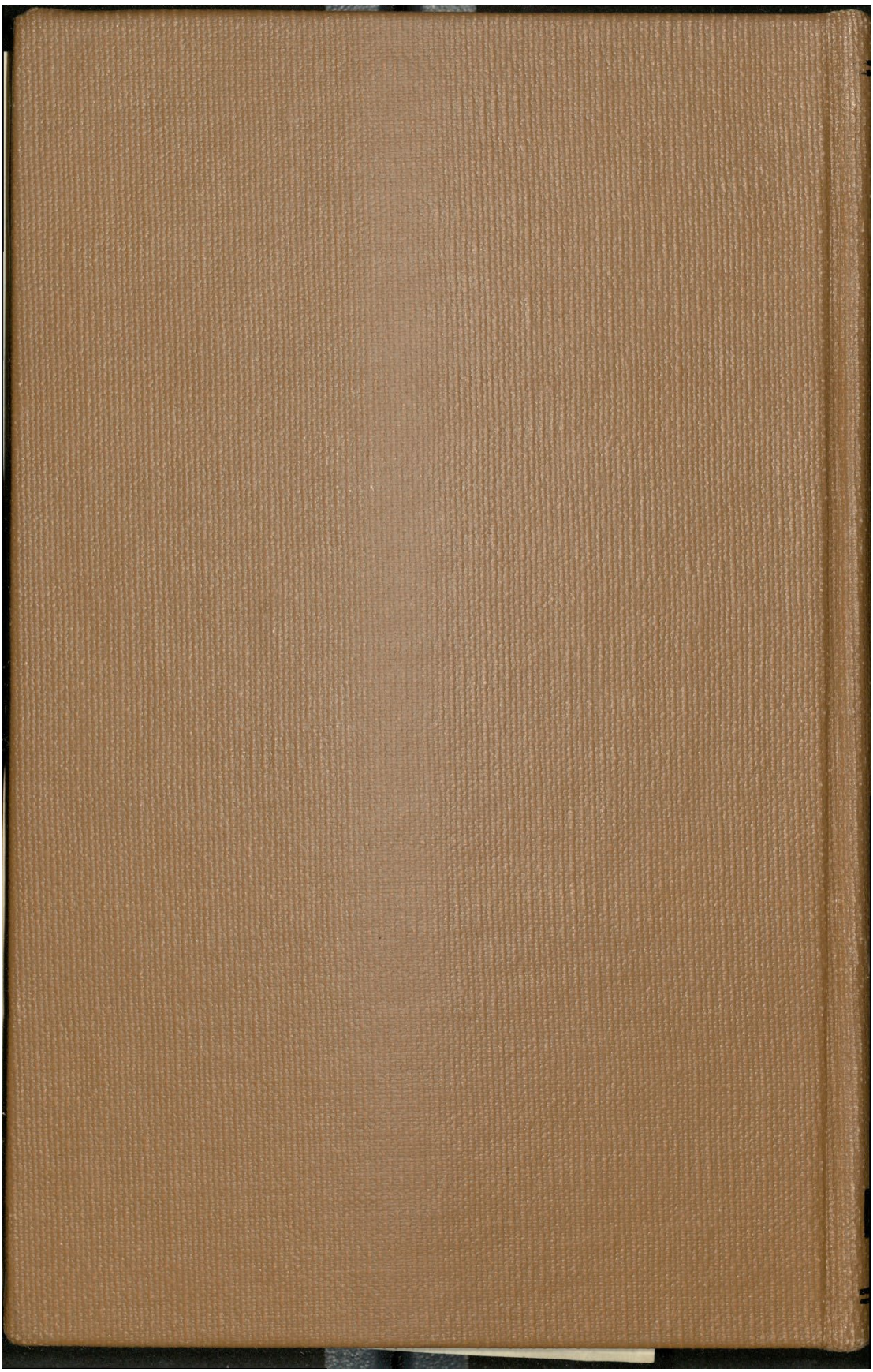
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